be adjusted as a function of a temperature within the curing chamber. The thermocouple may be located at numerous positions proximate the mold cavity and/or casting chamber.

The wavelength and intensity of the second activating rays are preferably substantially equal to those of the first activating rays. It may be desirable to vary the intensity and/or wavelength of the radiation (e.g., first or second activating rays). The particular wavelength and intensity of the radiation employed may vary among embodiments according to such factors as the identity of the composition and curing cycle variables.

Numerous curing cycles may be designed and employed. The design of an optimal cycle should include consideration of a number of interacting variables. Significant independent variables include: 1) the mass of the sample of lens forming material, 2) the intensity of the light applied to the material, 3) the physical characteristics of the lens forming material, and 4) the cooling efficiency of the system. Significant curing cycle (dependent) variables include: 1) the optimum initial exposure time for induction and gelling, 2) the total cycle time, 3) the time period between pulses, 4) the duration of the pulses, and 5) the total exposure time.

Most of the experiments involving these methods were conducted using below described OMB-91 monomer. The OMB-91 formulation and properties are listed below.

OMB-91 FORMULATION:

INGREDIENT	WEIGHT PERCENT		
Sartomer SR 351 (Trimethylolpropane Triacrylate)	20.0	+/-	1.0
Sartomer SR 268 (Tetraethylene Glycol Diacrylate)	21.0	+/-	1.0
Sartomer SR 306 (Tripropylene Glycol Diacrylate)	32.0	+/-	1.0
Sartomer SR 239 (1,6 Hexanediol Dimethacrylate)	10.0	+/-	1.0
(Bisphenol A Bis(Allyl Carbonate))	17.0	+/-	1.0
Irgacure 184 (1-Hydroxycyclohexyl Phenyl Ketone)	0.017	+/-	0.0002
Methyl Benzoyl Formate	0.068	+/-	0.0007
Methyl Ester of Hydroquinone ("MeHQ")	35 ppm	+/-	10 ppm
Thermoplast Blue P (9,10 - Anthracenedione, 1-hydroxy-4-((4-methyl phenyl) Amino)	0.35 ppm	+/-	0.1 ppm

MEASUREMENTS/PROPERTIES:

PROPERTY	PROPOSED SPECIFICATION
Appearance	Clear Liquid
Color	
(APHA)	50 maximum
(Test Tube Test)	Match Standard
Acidity (ppm as Acrylic Acid)	100 maximum
Refractive Index	1.4725 +/- 0.002
Density	1.08 +/- 0.005 gm/cc. at 23 °C.
Viscosity @ 22.5 Degrees C.	27.0 +/- 2 centipoise
Solvent Weight (wt %)	0.1 Maximum
Water (wt %)	0.1 Maximum
MeHQ (from HPLC)	35 ppm +/- 10 ppm

It should be recognized that methods and systems disclosed could be applied to a large variety of radiation-curable, lens forming materials in addition to those mentioned herein. It should be understood that adjustments to curing cycle variables (particularly the initial exposure time) may be required even among lens forming compositions of the same type due to variations in inhibitor levels among batches of the lens forming compositions. In addition, changes in the heat removal capacity of the system may require adjustments to the curing cycle variables (e.g. duration of the cooling periods between radiation pulses). Changes in the cooling capacity of the system and/or changes in compositions of the lens forming material may require adjustments to curing cycle variables as well.

Significant variables impacting the design of a pulsed curing cycle include (a) the mass of the material to be cured and (b) the intensity of the activating light applied to the

material. If a sample is initially overdosed with radiation, the reaction may progress too far and increase the likelihood of premature release and/or cracking. If a sample is underdosed initially in a fixed (i.e., preset) curing cycle, subsequent exposures may cause too great a temperature rise later in the cycle, tending to cause premature release and/or cracking. Additionally, if the light intensity varies more than about +/- 10% in a cycle that has been designed for a fixed light intensity level and/or fixed mass of lens forming material, premature release and/or cracking may result.

An embodiment involves a curing cycle having two processes. A first process relates to forming a dry gel by continuously irradiating a lens forming composition for a relatively long period. The material is preferably cooled down to a lower temperature under darkness, after the irradiation is complete. A second process relates to controllably discharging the remaining exothermic potential of the material by alternately exposing the material to relatively short periods of irradiation and longer periods of decreased irradiation (e.g., dark cooling).

The behavior of the lens forming material during the second process will depend upon the degree of reaction of the lens forming material that has occurred during the first process. For a fixed curing cycle, it is preferable that the extent of reaction occurring in the first process consistently fall within a specified range. If the progress of reaction is not controlled well, the incidence of cracking and/or premature release may rise. For a curing cycle involving a composition having a constant level of inhibitor and initiator, the intensity of the radiation employed is the most likely source of variability in the level of cure attained in the first process. Generally, a fluctuation of +/- 5% in the intensity tends to cause observable differences in the cure level achieved in the first process. Light intensity variations of +/- 10% may significantly reduce yield rates.

The effect of various light intensities on the material being cured depends upon whether the intensity is higher or lower than a preferred intensity for which the curing

cycle was designed. Fig. 25 shows temperature profiles for three embodiments in which different light levels were employed. If the light intensity to which the material is exposed is higher than a preferred intensity, the overdosage may cause the reaction to proceed too far. In such a case, excessive heat may be generated, increasing the possibility of cracking and/or premature release during the first process of the curing cycle. If premature release or cracking of the overdosed material does not occur in the first process, then subsequent pulses administered during the second process may create very little additional reaction.

If the light intensity is lower than a preferred intensity and the lens forming material is underdosed, other problems may arise. The material may not be driven to a sufficient level of cure in the first process. Pulses applied during the second process may then cause relatively high amounts of reaction to occur, and the heat generated by reaction may be much greater than the heat removal capacity of the system. Thus the temperature of the lens forming material may tend to excessively increase. Premature release may result. Otherwise, undercured lenses that continue generating heat after the end of the cycle may be produced.

The optimal initial radiation dose to apply to the lens forming material may depend primarily upon its mass. The initial dose may also be a function of the light intensity and exposure time. A method for designing a curing cycle for a given mold/gasket/monomer combination may involve selecting a fixed light intensity.

The methods disclosed may involve a wide range of light intensities. Using a relatively low intensity may allow for the length of each cooling step to be decreased such that shorter and more controllable pulses are applied. Where a fluorescent lamp is employed, the use of a lower intensity may allow the use of lower power settings, thereby reducing the load on the lamp cooling system and extending the life of the lamp. A disadvantage of using a relatively low light intensity is that the initial exposure period

may be somewhat longer. Relatively high intensity levels tend to provide shorter initial exposure times while placing more demand upon the lamp drivers and/or lamp cooling system, either of which tends to reduce the life of the lamp.

Once a light intensity is selected, the initial exposure time may be determined. A convenient method of monitoring the reaction during the cycle involves fashioning a fine gauge thermocouple, positioning it inside the mold cavity, and connecting it to an appropriate data acquisition system. A preferred thermocouple is Type J, 0.005 inch diameter, Teflon-insulated wire available from Omega Engineering. The insulation is preferably stripped back about 30 to 50 mm and each wire is passed through the gasket wall via a fine bore hypodermic needle. The needle is preferably removed and the two wires may be twisted together to form a thermocouple junction inside the inner circumference of the gasket. The other ends of the leads may be attached to a miniature connector which may be plugged into a permanent thermocouple extension cord leading to the data acquisition unit after the mold set is filled.

The data acquisition unit may be a Hydra 2625A Data Logger made by John Fluke Mfg. Company. It is preferably connected to an IBM compatible personal computer running Hydra Data Logger software. The computer is preferably configured to display a trend plot as well as numeric temperature readings on a monitor. The scan interval may be set to any convenient time period and a period of five or ten seconds usually provides good resolution.

The position of the thermocouple junction in the mold cavity may affect its reading and behavior through the cycle. When the junction is located between the front and back molds, relatively high temperatures may be observed compared to the temperatures at or near the mold face. The distance from the edge of the cavity to the junction may affect both absolute temperature readings as well as the shape of the curing cycle's temperature plot. The edges of the lens forming material may begin to increase in

temperature slightly later than other portions of the material. Later in the cycle, the lens forming material at the center may be somewhat ahead of the material at the edge and will tend to respond little to the radiation pulses, whereas the material near the edge may tend to exhibit significant activity. When performing experiments to develop curing cycles, it is preferred to insert two probes into the mold cavity, one near the center and one near the edge. The center probe should be relied upon early in the cycle and the edge probe should guide the later stages of the cycle.

Differing rates of reaction among various regions of the lens forming material may be achieved by applying a differential light distribution across the mold face(s). Tests have been performed where "minus type" light distributions have caused the edge of the lens forming material to begin reacting before the center of the material. The potential advantages of using light distributing filters to cure high mass semi-finished lenses may be offset by non-uniformity of total light transmission that tends to occur across large numbers of filters.

After the selection and/or configuration of (a) the radiation intensity, (b) the radiation-curable, lens forming material, (c) the mold/gasket set, and (d) the data acquisition system, the optimum initial exposure period may be determined. It is useful to expose a sample of lens forming material to continuous radiation to obtain a temperature profile. This will provide an identifiable range of elapsed time within which the optimal initial exposure time will fall. Two points of interest may be the time where the temperature rise in the sample is first detected ("T initial" or "Ti"), and the time where the maximum temperature of the sample is reached ("Tmax"). Also of interest is the actual maximum temperature, an indication of the "heat potential" of the sample under the system conditions (e.g., in the presence of cooling).

As a general rule, the temperature of high mass lenses (i.e., lenses greater than about 70 grams) should remain under about 200 °F and preferably between about 150 °F

and about 180 °F. Higher temperatures are typically associated with reduced lens yield rates due to cracking and/or premature release. Generally, the lower mass lenses (i.e., lenses no greater than about 45 grams) should be kept under about 150 °F and preferably between about 110 °F and about 140 °F.

The first period may be selected according to the mass of the lens forming material. In an embodiment, the lens forming material has a mass of between about 45 grams and about 70 grams and a selected second temperature between about 150 °F and about 200 °F. According to another embodiment, the lens forming material has a mass no greater than about 45 grams and a second temperature less than about 150 °F. In yet another embodiment, the lens forming material has a mass of at least about 70 grams, and a second temperature between about 170 °F and about 190 °F.

An experiment may be performed in which the radiation is removed from the mold members slightly before one-half of the time between T initial and Tmax. The initial exposure time may be interactively reduced or increased according to the results of the above experiment in subsequent experiments to provide a Tmax in a preferred range. This procedure may allow the determination of the optimal initial exposure time for any given mold/gasket set and light intensity.

A qualitative summary of relationships among system variables related to the above-described methods is shown in Fig. 24.

After the initial exposure period, a series of irradiation pulse/cooling steps may be performed to controllably discharge the remaining exothermic potential of the material and thus complete the cure. There may be at least two approaches to accomplish this second process. The first involves applying a large number of very short pulses and short cooling periods. The second approach involves applying a fewer number of longer pulses

with correspondingly longer cooling periods. Either of these two methods may produce a good product and many acceptable cycles may exist between these extremes.

The described method relates to using pulsed application of light to produce a large range (e.g., from -6 to +4 diopter) of lenses without requiring refrigerated cooling fluid (e.g., cooled air). With proper light application, air at ambient may be used as a cooling fluid, thus significantly reducing system costs.

The following general rules for the design of pulse/cooling cycles may be employed to allow rapid curing of a lens while inhibiting premature release and/or cracking of the lens. The duration of the pulses preferably does not result in a temperature that exceeds the maximum temperature attained in the initial exposure period. The length of the cooling period may be determined by the length of time necessary for the internal temperature of the lens forming material to return to near the temperature it had immediately before it received a pulse. Following these general rules during routine experimentation may permit proper curing cycles to be established for a broad range of lens forming materials, light intensity levels, and cooling conditions.

Preferably, light output is measured and controlled by varying the amount of power applied to the lights in response to changes in light output. Specifically, a preferred embodiment includes a light sensor mounted near the lights. This light sensor measures the amount of light, and then a controller increases the power supplied to maintain the first activating light rays as the intensity of the first activating light rays decreases during use, and vice versa. Preferably, the power is varied by varying the electric frequency supplied to the lights.

In an embodiment, a medium pressure mercury vapor lamp is used to cure the lens forming material and the lens coating. This lamp and many conventional light sources used for activating light curing may not be repeatedly turned on and off since a

several minute warm-up period is generally required prior to operation. Mercury vapor light sources may be idled at a lower power setting between exposure periods (i.e., second periods), however, the light source will still generate significant heat and consume electricity while at the lower power setting.

In an embodiment, air at ambient temperature may be used to cool the lens forming composition. When a xenon flash lamp is used, the pulses of light generally have a duration of much less than about one second and considerably less radiative heat tends to be transferred to the lens forming composition compared to curing methods employing other activating light sources. Thus, the reduced heat imparted to the lens forming composition may allow for air at ambient temperature to remove sufficient heat of exotherm to substantially inhibit premature release and/or cracking of the lens.

In an embodiment, a xenon source is used to direct first activating light rays toward the first and second mold members to the point that a temperature increase is measured and/or the lens forming composition begins to or forms a gel. It is preferred that the gel is formed with less than 15 pulses of radiation, and more preferably with less than about 5 pulses. It is preferred that the gel is formed before the total time to which the composition has been exposed to the pulses exceeds about 1/10 or 1/100 of a second.

In an embodiment, a reflecting device is preferably employed in conjunction with the xenon light source. The reflecting device is positioned behind the flash source and preferably allows an even distribution of activating light rays from the center of the composition to the edge of the composition.

In an embodiment, a xenon light flash lamp is preferably used to apply a plurality of activating light pulses to the lens forming composition to cure it to an eyeglass lens in a time period of less than 30 minutes, or more preferably, less than 20 or 15 minutes.

The use of a xenon light source also may allow the formation of lenses over a wider range of diopters. Higher power lenses exhibit greatest thinnest to thickest region ratios, meaning that more shrinkage-induced stress may be created, causing greater mold flexure and thus increased tendency for premature release. Higher power lenses also possess thicker regions. Portions of lens forming material within these thicker regions may receive less light than regions closer to the mold surfaces. Continuous irradiation lens forming techniques typically require the use of relatively low light intensities to control the heat generated during curing. The relatively low light intensities used tends to result in a long, slow gellation period. Optical distortions tend to be created when one portion of the lens is cured at a different rate than another portion. Methods characterized by non-uniform curing are typically poorly suited for the production of relatively high power lenses, since the deeper regions (e.g., regions within a thick portion of a lens) tend to gel at a slower rate than regions closer to the mold surfaces.

The relatively high intensity attainable with the xenon source may allow deeper penetration into, and/or saturation of, the lens forming material, thereby allowing uniform curing of thicker lenses than in conventional radiation-initiated curing. More uniform gelation may occur when the lens forming material is dosed with a high intensity pulse of activating light and then subjected to decreased activating light or darkness as the reaction proceeds without activating radiation. Lenses having a diopter of between about +5.0 and about -6.0 and greater may be cured. It is believed that light distribution across the sample is less critical when curing and especially when gelation is induced with relatively high intensity light. The lens forming material may be capable of absorbing an amount of energy per time that is below that delivered during a relatively high intensity pulse. The lens forming material may be "oversaturated" with respect to the light delivered via a high intensity flash source. In an embodiment, the xenon source is preferably used to cure a lens having a diopter between about -4.0 and about -6.0. In an

embodiment, the xenon source is preferably used to cure a lens having a diopter between about +2.0 and about +4.0.

The methods disclosed herein allow curing of high-mass semi-finished lens blanks from the same material used to cure cast-to-finish lenses. Both are considered to be "eyeglass lenses" for the purposes of this patent. These methods may also be used to cure a variety of other lens forming materials. These methods have been successfully used to make cast-to-finish lenses in addition to semi-finished lenses.

6. Improved Lens Curing Process

When casting an eyeglass lens with activating light, the gelation pattern of the lens forming composition may affect the resultant optical quality of the lens. If there are localized discontinuities in the light intensities received by the monomer contained in the casting cavity during the early stages of the polymerization process, optical distortions may be seen in the finished product. Higher power lenses are, by definition, thicker in certain regions than relatively lower power lenses of the same diameter. The layers of a lens closest to the mold faces of the casting cavity tend to receive a higher light intensity than the deeper layers because the lens forming composition absorbs some of the incident light. This causes the onset of polymerization to be delayed in the deeper layers relative to the outer layers, which may cause optical distortions in the finished product. It is believed that concurrent with this differential curing rate, there is a difference in the rate of exothermic heat generation, specifically, the deeper regions will begin to generate heat after the outer regions in the cavity have already cured and the effectiveness of the heat removal may be impaired, contributing to optical waves and distortions in the finished product. This phenomena is particularly observable in high powered positive lenses due to the magnification of such defects.

In an embodiment, the lens forming composition contained within the casting cavity is exposed to relatively high intensity activating light for a time period sufficient to initialize the reaction. Irradiation is preferably terminated before the polymerization of the lens forming composition proceeds far enough to generate a substantial amount of heat. This initial relatively high intensity dose preferably substantially uniformly gels the material within the casting cavity such that the difference in the rate of reaction between the inner and outer layers of the lens being cured is preferably reduced, thereby eliminating the waves and distortions often encountered when using continuous low intensity irradiation to initialize the reaction, particularly with high dioptric power positive lenses.

In an embodiment, the relatively high intensity dose of activating light is preferably applied to the lens forming composition in the form of pulses. The pulses preferably have a duration of less than about 10 seconds, preferably less than about 5 seconds, and more preferably less than about 3 seconds. The pulses preferably have an intensity of at least about 10 milliwatts/cm^2, more preferably at least about 100 milliwatts/cm^2, and more preferably still between about 150 milliwatts/cm^2 and about 250 milliwatts/cm^2. It is preferred that substantially all of the lens forming composition forms into a gel after the initial application of the relatively high intensity activating light. In an embodiment, no more than an insubstantial amount of heat is generated by exothermic reaction of the lens forming composition during the initial application of the relatively high intensity activating light.

Subsequent to this initial high intensity dose, a second irradiation step may be performed in which the material contained within the casting cell is preferably irradiated for a relatively longer time at a relatively lower intensity while cool fluid is directed at the non-casting surface of at least one of the molds forming the cavity. The cooling fluid preferably removes the exothermic heat generated by the polymerization of the lens forming composition. If the intensity of the activating light is too great during this second irradiation step, the rate of heat generation will tend to be too rapid and the lens

may release prematurely from the casting face of the mold and/or crack. Similarly, should the rate of heat removal from the lens forming composition be too slow, the lens may release prematurely and/or crack. It is preferred that the mold/gasket assembly containing the lens forming composition be placed within the cooling environment as shortly after the initial dose of activating light as possible.

In an embodiment, the activating light applied to the lens forming composition during the second irradiation step is preferably less than about 350 microwatts/cm^2, more preferably less than about 150 microwatts/cm^2, and more preferably still between about 90 microwatts/cm^2 and about 100 microwatts/cm^2. During the second irradiation step, the activating light may be applied to the lens forming composition continuously or in pulses. A translucent high density polyethylene plate may be positioned between the activating light generator and at least one of the mold members to reduce the intensity of the activating light to within a preferred range.

In an embodiment, relatively high intensity activating light is preferably applied to the lens curing composition in a third irradiation step to post-cure the lens subsequent to the second relatively low intensity irradiation step. In the third irradiation step, pulses of activating light are preferably directed toward the lens forming composition, although the composition may be continuously irradiated instead. The pulses preferably have an intensity of at least about 10 milliwatts/cm^2, more preferably at least about 100 milliwatts/cm^2, and more preferably still between about 100 milliwatts/cm^2 and about 150 milliwatts/cm^2.

Each of the above-mentioned irradiation steps is preferably performed by directing the activating light through each of the first and second mold members. The eyeglass lens is preferably cured in a total time of less than 30 minutes and is preferably free of cracks, striations, distortions, haziness, and yellowness.

It is believed that the above-described methods enable the production of whole lenses in prescription ranges beyond those currently attainable with continuous low intensity irradiation. The method may be practiced in the curing of relatively high or low power lenses with a reduced incidence of optical distortions in the finished lens as compared to conventional methods. It is to be understood that the above-described methods may be used independently or combined with the methods and apparatus of preferred embodiments described above in the previous sections.

7. Improved Scratch Resistant Lens Formation Process

The "in-mold" method involves forming a scratch resistant coating over an eyeglass lens by placing the liquid coating in a mold and subsequently curing it. The in-mold method may be advantageous to "out-of-mold" methods since the in-mold method exhibits less occurrences of coating defects manifested as irregularities on the anterior surface of the coating. Using the in-mold method produces a scratch resistant coating that replicates the topography and smoothness of the mold casting face. However, a problem encountered when using conventional in-mold scratch resistant coatings is that minute "pinholes" often form in the coating. It is believed that the pinholes may be caused by either contaminants on the mold, airborne particles falling on the coating before it is cured, or bubbles formed during the application of the coating which burst afterwards. The formation of such pinholes is especially prevalent when using a flat-top bifocal mold, such as the one depicted in Fig. 29. As illustrated, the segment line 454 of a bifocal segment 452 below the main surface 456 of the mold reduces the smoothness of the casting face. When a coating is spin-coated over the mold face, this indentation may become an obstacle to the even flow of the casting face. The pinhole defects may be a problem in tinted lenses because the dye used to tint a lens may penetrate through the pinholes, resulting in a tiny speck of dye visible in the lens.

According to an embodiment, a first coating composition (i.e., a polymerizable "primer" material) is preferably passed through a filter and then placed within a mold member having a casting face and a non-casting face. The first coating composition preferably contains a photoinitiator to make it curable upon exposure to activating light. The mold member may then be spun so that the first composition becomes distributed over the casting face. The mold member may be rotated about a substantially vertical axis at a speed between about 750 and about 1500 revolutions per minute, preferably between about 800 and about 1000 revolutions per minute, more preferably at about 900 revolutions per minute. Further, a dispensing device may be used to direct an additional amount of the first composition onto the casting face while the mold member is spinning. The dispensing device preferably moves from the center of the mold member to an edge of the mold member so that the additional amount is preferably directed along a radius of the mold member. Activating light is preferably directed at the mold member to cure at least a portion of the first composition.

A second coating composition may then be placed upon the first composition in the mold member. The second coating is also preferably curable when exposed to activating light because it contains a photoinitiator. The mold member is preferably spun to distribute the second coating composition over the cured portion of the first coating composition. The mold member may also be spun simultaneously while adding the second composition to the mold member. Activating light is then preferably directed at the mold member to simultaneously cure at least a portion of the second coating composition and form a transparent combination coat having both coating compositions. The combination coat is preferably a substantially scratch-resistant coating. The mold member may then be assembled with a second mold member by positioning a gasket between the members to seal them. Therefore, a mold having a cavity shared by the original two mold members is formed. An edge of the gasket may be displaced to insert a lens-forming composition into the cavity. The combination coat and the lens-forming material preferably adhere well to each other. This lens-forming composition preferably

comprises a photoinitiator and is preferably cured using activating light. Air which preferably has a temperature below ambient temperature may be directed toward a non-casting face of the second mold member to cool the lens-forming composition while it is being cured.

The primer coat preferably comprises a mixture of high viscosity monomers, a low viscosity, low flashpoint organic solvent, and a suitable photoinitiator system. The solvent may make up more than about 80 % of the mixture, preferably about 93% to 96%. This mixture preferably has low viscosity and preferably covers any surface irregularity during the spin application, for example the segment line of a flat-top bifocal mold. The low flashpoint solvent preferably evaporates off relatively quickly, leaving a thin layer of high viscosity monomer, containing photoinitiator, which coats the casting face of the mold. The cured primer coat is preferably soft to allow it to adhere well to the glass mold face. Since the primer coat is soft, it may not possess scratch resistant characteristics. However, applying a high scratch resistance hard coating (i.e., the second coating composition) to the primer coat preferably results in a scratch resistant combination coat. The hard coat preferably contains a solvent which evaporates when the mold member is rotated to distribute the hard coating over the primer coat.

In general, the ideal primer material preferably possesses the following characteristics: exhibits chemical stability at normal storage conditions (e.g., at room temperature and in the absence of activating light); flows well on an irregular surface, especially over a flat-top bifocal segment; when cured with a specified activating light dose, leaves a crack-free coating, with a high double bond conversion (approximately greater than 80%); maintains adhesion with the mold face through the lens forming curing cycle, especially the segment part of the flat-top bifocal mold; and is chemically compatible with the hard coat that is subsequently applied on top of it (e.g., forms an optically clear combination coat). Even though pinhole defects may be present in either the primer coat or the hard coat, it is highly unlikely that defects in one coat would coincide with defects of another coat. Each coat preferably covers the holes of the other

coat, resulting in less pinholes in the combination coat. Thus, the finished in-mold coated lens may be tinted using dye without problems created by pinholes. It is also preferably free of cracks, yellowness, haziness, and distortions.

In an embodiment, the gasket between the first mold member and the second mold member may be removed after a portion of the lens-forming material has been cured. The removal of the gasket preferably exposes an edge of the lens. An oxygen barrier having a photoinitiator may be placed around the exposed edge of the lens, wherein the oxygen barrier photoinitiator is preferably near an uncured portion of the lens-forming composition. Additional activating light rays may then be directed towards the lens to cause at least a portion of the oxygen barrier photoinitiator to initiate reaction of the lens-forming material. The oxygen barrier preferably prevents oxygen from contacting at least a portion of the lens forming composition during exposure of the lens to the activating rays.

According to one embodiment, a substantially solid conductive heat source is preferably applied to one of the mold members. Heat may be conductively transferred from the heat source to a face of the mold member. Further, the heat may be conductively transferred through the mold member to the face of the lens.

8. Method for Forming a Plastic Lens Containing Ultraviolet/Visible Light Absorbing Compounds.

Materials (hereinafter referred to as "ultraviolet/visible light absorbing compounds") that absorb various degrees of ultraviolet/visible light may be used in an eyeglass lens to inhibit ultraviolet/visible light from being transmitted through the eyeglass lens. Such an eyeglass lens advantageously inhibits ultraviolet/visible light from being transmitted to the eye of a user wearing the lens. Curing of an eyeglass lens using activating light to initiate the polymerization of a lens forming composition generally

requires that the composition exhibit a high degree of activating light transmissibility so that the activating radiation may penetrate to the deeper regions of the lens cavity. Otherwise the resulting cast lens may possess optical aberrations and distortions. The cast lens may also contain layers of cured material in the regions closest to the transparent mold faces, sandwiching inner layers which may be either incompletely cured, gelled, barely gelled, or even liquid. Often, when even small amounts of ultraviolet/visible light absorbing compounds of the types well known in the art are added to a normally activating light curable lens forming composition, substantially the entire amount of lens forming composition contained within the lens cavity may remain liquid in the presence of activating radiation.

Photochromic pigments which have utility for photochromic eyeglass lenses absorb ultraviolet/visible light strongly and change from an unactivated state to an activated state when exposed to ultraviolet/visible light. The presence of photochromic pigments, as well as other ultraviolet/visible light absorbing compounds within a lens forming composition, generally does not permit enough activating radiation to penetrate into the depths of the lens cavity sufficient to cause photoinitiators to break down and initiate polymerization of the lens forming composition. Thus, it may be difficult to cure a lens forming composition containing ultraviolet/visible light absorbing compounds using activating light. It is therefore desirable to provide a method for using activating light to initiate polymerization of an eyeglass lens forming monomer which contains ultraviolet/visible light absorbing compounds, in spite of the high activating light absorption characteristics of the ultraviolet/visible light absorbing compounds. Examples of such ultraviolet/visible light absorbing compounds other than photochromic pigments are fixed dyes and colorless additives.

In an embodiment, an ophthalmic eyeglass lens may be made from a lens forming composition comprising a monomer, an ultraviolet/visible light absorbing compound, an photoinitiator, and a co-initiator. Examples of these compounds are listed in the section

"Lens Forming Compositions Including Ultraviolet/Visible Light Absorbing Materials". The lens forming composition, in liquid form, is preferably placed in a mold cavity defined by a first mold member and a second mold member. It is believed that activating light, which is directed toward the mold members to activate the photoinitiator, causes the photoinitiator to form a polymer chain radical. The polymer chain radical preferably reacts with the co-initiator more readily than with the monomer. The co-initiator may react with a fragment or an active species of either the photoinitiator or the polymer chain radical to produce a monomer initiating species in the regions of the lens cavity where the level of activating light is either relatively low or not present.

The co-initiator is preferably activated only in the presence of the photoinitiator. Further, without the co-initiator, the photoinitiator may exclusively be activated near the surface of the lens forming composition but not within the middle portion of the composition. Therefore, using a suitable photoinitiator combined with a co-initiator permits polymerization of the lens forming composition to proceed through the depths of the lens cavity. A cured, clear, aberration free lens is preferably formed in less than about 30 minutes, more preferably in less than about 10 minutes. The lens, when exposed to ultraviolet/visible light preferably inhibits at least a portion of the ultraviolet/visible light from being transmitted through the lens that is preferably formed. A lens that permits no ultraviolet light from passing through the lens (at least with respect to certain ultraviolet wavelengths) is more preferred.

The identity of the major polymerizable components of the lens forming composition tends to affect the optimal curing process. It is anticipated that the identity of the ultraviolet/visible light absorbing compound present in the monomer or blend of monomers may affect the optimal photoinitiator/co-initiator system used as well as the optimal curing process used to initiate polymerization. Also, varying the identities or the proportions of the monomer(s) in the lens forming composition may require adjustments to various production process variables including, but not limited to, exposure times,

exposure intensities, cooling times and temperatures, activating light and thermal postcure procedures and the like. For example, compositions comprising relatively slow reacting monomers, such as bisphenol A bis allyl carbonate or hexanediol dimethacrylate, or compositions comprising relatively higher proportions of such monomers may require either longer exposure times, higher intensities, or both. It is postulated that increasing the amount of either fast reacting monomer or the initiator levels present in a system will require reduced exposure times, more rigidly controlled light doses, and more efficient exothermic heat removal.

Exothermic reactions may occur during the curing process of the lens forming composition. The thicker portions of the lens forming composition may generate more heat than the thinner portions of the composition as a result of the exothermic reactions taking place. It is believed that the speed of reaction in the thicker sections is slower than in the thinner sections. Thus, in a positive lens a "donut effect" may occur in which the relatively thin outer portion of the lens forming composition reaches its fully cured state before the relatively thick inner portion of the lens forming composition. Conversely, in a negative lens the relatively thin inner portion of the lens forming composition may reach its fully cured state before the relatively thick outer portion of the lens forming composition.

After the lens forming composition is preferably loaded into a mold assembly, the mold assembly is preferably irradiated with activating light at an appropriate intensity and duration. Typically, the intensity and duration of activating light required to produce a lens containing ultraviolet/visible light absorbers is preferably significantly higher than the intensity and duration of light required for forming non-ultraviolet/visible light absorbing lenses. The mold assembly may also require multiple doses for curing. This may require a different apparatus and/or setup from that used to form non-UV absorbing lenses.

In one embodiment, an apparatus may be capable of forming clear, colored, or ›tochromic lenses without significantly altering the apparatus. In order to achieve this the lens forming composition will preferably include ultraviolet/visible light absorbers. By placing ultraviolet/visible light absorbers in a clear non-photochromic lens forming composition, a clear lens may be obtained under similar conditions to those used for colored and photochromic lenses. Thus, the addition of ultraviolet/visible light absorbers to a non-photochromic lens forming composition, allows both photochromic and non-photochromic lens forming compositions to be cured using the same apparatus and similar procedures. An added advantage, is that the produced clear lenses provide additional ultraviolet/visible light protection to the user that may not be present in clear lenses formed without ultraviolet/visible light absorbers. In this manner, plastic lenses may be formed which exhibit many of the same properties as glass lenses however, the plastic lenses may be produced more rapidly, at lower cost, and have a weight significantly less than their glass counterparts.

<u>9. Actinic Light Initiated Polymerization Ultraviolet/Visible Light Absorbing Compositions.</u>

Curing of an eyeglass lens using activating light to initiate the polymerization of a lens forming composition generally requires that the composition exhibit a high degree of activating light transmissibility so that the activating light may penetrate to the deeper regions of the lens cavity. Otherwise the resulting cast lens may possess optical aberrations and distortions. The cast lens may also contain layers of cured material in the regions closest to the transparent mold faces, sandwiching inner layers which may be either incompletely cured, gelled, barely gelled, or even liquid. Often, when even small amounts of activating light absorbing compounds have been added to a normally curable lens forming composition, substantially the entire amount of lens forming composition contained within the lens cavity may remain liquid in the presence of activating light.

Photochromic pigments that have utility for photochromic eyeglass lenses typically absorb activating light strongly and change from an inactivated state to an activated state when exposed to activating light. The presence of photochromic pigments, as well as other activating light absorbing compounds within a lens forming composition, generally does not permit enough activating radiation to penetrate into the depths of the lens cavity sufficient to cause photoinitiators to break down and initiate polymerization of the lens forming composition. Examples of such activating light absorbing compounds other than photochromic pigments are fixed dyes and colorless additives.

It is therefore difficult to cure a lens forming composition containing activating light absorbing compounds using activating light. One solution to this problem involves the use of a co-initiator. By using a co-initiator, activating light may be used to initiate the polymerization reaction. It is believed that activating light that is directed toward the mold members may cause the photoinitiator to form a polymer chain radical. The polymer chain radical preferably reacts with the co-initiator more readily than with the monomer. The co-initiator may react with a fragment or an active species of either the photoinitiator or the polymer chain radical to produce a monomer initiating species in the regions of the lens cavity where the level of activating light is either relatively low or not present. It is therefore desirable to provide a method for polymerizing an eyeglass lens forming composition that contains light absorbing compounds by using activating light having a wavelength that is not absorbed by the light absorbing compounds, thus avoiding the need for a co-initiator.

In an embodiment, an ophthalmic eyeglass lens may be made from a lens forming composition comprising a monomer, a light absorbing compound, and a photoinitiator, by irradiation of the lens forming composition with activating light. As used herein "activating light" means light that may effect a chemical change. Activating light may include ultraviolet light, actinic light, visible light or infrared light. Generally any wavelength of light capable of effecting a chemical change may be classified as

activating. Chemical changes may be manifested in a number of forms. A chemical change may include, but is not limited to, any chemical reaction which causes a polymerization to take place. Preferably the chemical change causes the formation of a initiator species within the lens forming composition, the initiator species being capable of initiating a chemical polymerization reaction.

The lens forming composition, in liquid form, is preferably placed in a mold cavity defined by a first mold member and a second mold member. It is believed that activating light, when directed toward and through the mold members to activate the photoinitiator, causes the photoinitiator to form a polymer chain radical. The polymer chain radical may react with a fragment or an active species of either photoinitiator or the polymer chain radical to produce a monomer initiating species in other regions of the lens cavity.

The use of activating light of the appropriate wavelength preferably prevents the lens from darkening during the curing process. Herein, "darkening" means becoming at least partially non-transparent to the incoming activating light such that the activating light may not significantly penetrate the lens forming composition. Photochromic compounds may cause such darkening. Ultraviolet/visible light absorbing compounds present in the lens forming composition may prevent activating light having a wavelength substantially below about 380 nm from penetrating into the lens forming composition. When treated with activating light containing light with wavelengths in the ultraviolet region, e.g. light with wavelengths below about 380 nm, the ultraviolet/visible light absorbing compounds may darken, preventing further ultraviolet activating light from penetrating the lens forming composition. The darkening of the lens forming composition may also prevent non-ultraviolet activating light from penetrating the composition. This darkening effect may prevent activating light of any wavelength from initiating the polymerization reaction throughout the lens forming composition.

When the ultraviolet/visible light absorbing compounds absorb in the ultraviolet region, activating light having a wavelength above about 380 nm (e.g., actinic light) may be used to prevent the darkening effect. Because the wavelength of the activating light is substantially above the wavelength at which the ultraviolet/visible light absorbing compounds absorb, the darkening effect may be avoided. Additionally, activating light with a wavelength above about 380 nm may be used to initiate the polymerization of the lens forming material. By the use of such activating light an eyeglass lens containing ultraviolet/visible light absorbing compounds may, in some circumstances, be formed without the use of a co-initiator.

In an embodiment, the above-described lens forming composition, where the ultraviolet/visible light absorbing compound absorbs, predominantly, ultraviolet light, may be treated with activating light having a wavelength above about 380 nm to activate the photoinitiator. Preferably, activating light having a wavelength substantially between about 380 nm to 490 nm is used. By using activating light above about 380 nm the darkening effect caused by the ultraviolet/visible light absorbing compounds may be avoided. The activating light may penetrate into the lens forming composition, initiating the polymerization reaction throughout the composition. A filter which blocks light having a wavelength that is substantially below about 380 nm may be used to prevent the ultraviolet/visible light absorbing compounds from darkening.

The use of activating light permits polymerization of the lens forming composition to proceed through the depths of the lens cavity. A cured, clear, aberration free lens is preferably formed in less than about 30-60 minutes, more preferably in less than about 20 minutes. As used herein a "clear lens" means a lens that transmits visible light without scattering so that objects beyond the lens may be seen clearly. As used herein "aberration" means the failure of a lens to produce point-to-point correspondence between an object and its image. The lens, when exposed to ultraviolet/visible light, preferably inhibits at least a portion of the ultraviolet/visible light from being transmitted

through the lens. In this manner the eye may be protected from certain light. A lens that permits no ultraviolet/visible light from passing through the lens (at least with respect to certain wavelengths) is more preferred.

In an embodiment, the lens forming composition that contains an ultraviolet/visible light absorbing compound may be cured with an activating light. Preferably, the activating light has a wavelength substantially above about 380 nm. The lens forming composition may be cured by exposing the composition to activating light multiple times. Alternatively, the lens forming composition may be cured by exposing the composition to a plurality of activating light pulses, at least one of the pulses having a duration of less than about one second (more preferably less than about 0.1 seconds, and more preferably between 0.1 and 0.001 seconds). Preferably, all activating light directed toward the mold members is at a wavelength between about 380 nm to 490 nm. The previously described embodiments which describe various methods and compositions for forming eyeglass lenses may also be utilized to form the eyeglass lens hereof, by replacing the ultraviolet light in these examples with activating light having a wavelength substantially greater than about 380 nm.

In an embodiment, the activating light may be generated from a fluorescent lamp. The fluorescent lamp is preferably used to direct activating light rays toward at least one of the mold members. At least one and preferably two fluorescent light sources, with strong emission spectra in the 380 to 490 nm region may be used. When two light sources are used, they are preferably positioned on opposite sides of the mold cavity. A fluorescent lamp emitting activating light with the described wavelengths is commercially available from Philips Electronics as model TLD-15W/03.

Preferably, three or four fluorescent lamps may be positioned to provide substantially uniform radiation over the entire surface of the mold assembly to be cured. The activating light source may be turned on and off quickly between exposures. A

flasher ballast may be used for this function. A flasher ballast may operate in a standby mode wherein a low current is supplied to the lamp filaments to keep the filaments warm and thereby reduce the strike time of the lamp. Such a ballast is commercially available from Magnatek, Inc of Bridgeport, Connecticut. Alternately, the light source may employ a shutter system to block the light between doses. This shutter system is preferably controlled by a micro-processor based control system in order to provide the necessary doses of light. A feedback loop may be used to control the light intensity so that intensity fluctuations due to environmental variables (e.g. lamp temperature) and lamp aging may be minimized. A light sensor may be incorporated into the control system to minimize variances in dose for a given exposure time.

The identity of the major polymerizable components of the lens forming composition tends to affect the optimal curing process. It is anticipated that the identity of the light absorbing compound present in the monomer or blend of monomers may affect the optimal photoinitiator system used as well as the optimal curing process used to initiate polymerization. Also, varying the identities or the proportions of the monomer(s) in the lens forming composition may require adjustments to various production process variables including, but not limited to, exposure times, exposure intensities, cooling times and temperatures, postcure procedures and the like. For example, compositions including relatively slow reacting monomers, such as bisphenol A bis allyl carbonate or hexanediol dimethacrylate, or compositions including relatively higher proportions of such monomers may require either longer exposure times, higher intensities, or both. It is postulated that increasing the amount of either fast reacting monomer or the initiator levels present in a system will require reduced exposure times, more rigidly controlled light doses, and more efficient exothermic heat removal.

Preferably, the monomers selected as components of the lens forming composition are capable of dissolving the light absorbing compounds added to them. As used herein "dissolving" means being substantially homogeneously mixed. For example,

monomers may be selected from a group including polyether (allyl carbonate) monomers, multi-functional acrylate monomers, and multi-functional methacrylic monomers for use in an ultraviolet/visible light absorbing lens forming composition.

In an embodiment, the mixture of monomers, previously described as PRO-629, may be blended together before addition of other components required to make the lens forming composition. This blend of monomers is preferably used as the basis for a lens forming composition to which ultraviolet/visible light absorbing compounds are added.

A polymerization inhibitor may be added to the monomer mixture at relatively low levels to inhibit polymerization of the monomer at inappropriate times (e.g., during storage). Preferably about 0 to 50 ppm of monomethylether hydroquinone (MEHQ) are added to the monomer mixture. It is also preferred that the acidity of the monomer mixture be as low as possible. Preferably less than about 100 ppm residual acrylic acid exists in the mixture. It is also preferred that the water content of the monomer mixture be relatively low, preferably less than about 0.15 percent.

Photoinitiators which have utility in the present method have been described in previous embodiments. Ultraviolet/visible light absorbing compounds which may be added to a normally ultraviolet/visible light transmissible lens forming composition have also been described in previous embodiments. The quantity of photochromic pigments present in the lens forming composition is preferably sufficient to provide observable photochromic effect. The amount of photochromic pigments present in the lens forming composition may widely range from about 1 ppm by weight to 1-5% by weight. In preferred compositions, the photochromic pigments are present in ranges from about 30 ppm to 2000 ppm. In the more preferred compositions, the photochromic pigments are present in ranges from about 150 ppm to 1000 ppm. The concentration may be adjusted depending upon the thickness of the lens being produced to obtain optimal visible light absorption characteristics.

In another embodiment co-initiators may be added to the lens forming composition. As described previously, such compositions may aid the polymerization of the lens forming composition by interacting with the photoinitiator such that the composition polymerizes in a substantially uniform manner. It is anticipated that the optimal amount of the initiators is where the total amount of both initiators are minimized subject to the constraint of complete polymerization and production of a rigid, aberration free lens. The relative proportions of the photoinitiator to the co-initiator may be optimized by experimentation. For example, an ultraviolet/visible light absorptive lens forming composition that includes a photoinitiator with no co-initiator may be cured. If waves and distortions are observed in the resulting lens, a co-initiator may then be added to the lens forming composition by increasing amounts until a lens having the best optical properties is formed. It is anticipated that excess co-initiator in the lens forming composition should be avoided to inhibit problems of too rapid polymerization, yellowing of the lens, and migration of residual, unreacted co-initiator to the surface of the finished lens.

In an embodiment, hindered amine light stabilizers may be added to the lens forming composition. It is believed that these materials act to reduce the rate of degradation of the cured polymer caused by exposure to ultraviolet light by deactivating harmful polymer radicals. These compounds may be effective in terminating oxygen and carbon free radicals, and thus interfering with the different stages of auto-oxidation and photo-degradation. Preferably, more than one monomer and more than one initiator are used in a lens forming composition to ensure that the initial polymerization of the lens forming composition with activating light does not occur over too short a period of time. The use of such a lens forming composition may allow greater control over the gel formation, resulting in better control of the optical quality of the lens.

An eyeglass lens formed using the lens forming compositions described may be applicable for use as a prescription lens and for a non-prescription lens. Particularly, such a lens may be used in sunglasses. Advantageously, photochromic sunglass lenses would remain light enough in color to allow a user to see through them clearly while at the same time prohibiting ultraviolet/visible light from passing through the lenses. In one embodiment, a background dye may be added to the photochromic lens to make the lens appear to be a dark shade of color at all times like typical sunglasses.

SPECIFIC EXAMPLES

The following examples are included to demonstrate embodiments of the invention. Those of skill in the art, in light of the present disclosure, should appreciate that many changes may be made in the specific examples that are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

EXAMPLE 1: Formation of a Plastic Lens by Curing With Activating Light

Formulation:	17%	Bisphenol A bis(allyl carbonate)
	10%	1,6 Hexanediol dimethacrylate
	20%	Trimethylolpropane triacrylate
	21%	Tetraethyleneglycol diacrylate
	32%	Tripropyleneglycol diacrylate
	0.012%	1 Hydroxycyclohexyl phenyl ketone
	0.048	Methyl benzoylformate
	<10 ppm	Hydroquinone & Methylethylhydroquinone

Hydroquinone and Methylethylhydroquinone were stabilizers present in some of the diacrylate and/or triacrylate compounds obtained from Sartomer. Preferably the amount of stabilizers is minimized since the stabilizers affect the rate and amount of curing. If

larger amounts of stabilizers are added, then generally larger amounts of photoinitiators must also be added.

Light Condition: mW/cm^2 measured at plane of sample with Spectroline DM 365N Meter from Spectronics Corp. (Westbury, N.Y.)

	Center	Edge
Top:	0.233	0.299
Bottom:	0.217	0.248

Air Flow: 9.6 standard cubic feet per minute ("CFM") per manifold - 19.2 CFM total on sample

Air Temperature: 4.4 degrees Centigrade

Molds: 80 mm diameter Corning #8092 glass

	Radius	Thickness
Concave:	170.59	2.7
Convex:	62.17	5.4

Gasket: General Electric SE6035 silicone rubber with a 3 mm thick lateral lip dimension and a vertical lip dimension sufficient to provide an initial cavity center thickness of 2.2 mm.

Filling: The molds were cleaned and assembled into the gasket. The mold/gasket assembly was then temporarily positioned on a fixture

which held the two molds pressed against the gasket lip with about 1 kg. of pressure. The upper edge of the gasket was peeled back to allow about 27.4 grams of the monomer blend to be charged into the cavity. The upper edge of the gasket was then eased back into place and the excess monomer was vacuumed out with a small aspirating device. It is preferable to avoid having monomer drip onto the noncasting surface of the mold because a drop tends to cause the activating light to become locally focused and may cause an optical distortion in the final product.

Curing: The sample was irradiated for fifteen minutes under the above conditions and removed from the lens curing unit. The molds were separated from the cured lens by applying a sharp impact to the junction of the lens and the convex mold. The sample was then postcured at 110 °C in the post-cure unit for an additional ten minutes, removed and allowed to cool to room temperature.

Results: The resulting lens measured 72 mm in diameter, with a central thickness of 2.0 mm, and an edge thickness of 9.2 mm. The focusing power measured ~5.05 diopter. The lens was water clear ("water-white"), showed negligible haze, exhibited total visible light transmission of about 94%, and gave good overall optics. The Shore D hardness was about 80. The sample withstood the impact of a 1 inch steel ball dropped from fifty inches in accordance with ANSI 280.1-1987, 4.6.4 test procedures.

EXAMPLE 2: Oxygen Barrier Example #1

A liquid lens forming composition was initially cured as in a process and

apparatus similar to that specified in Example 1. The composition was substantially the same as specified in Example 1, with the exception that hydroquinone was absent, the concentration of methylethylhydroquinone was about 25-45 ppm, the concentration of 1-hydroxycyclohexyl phenyl ketone was 0.017 percent, and the concentration of methylbenzoylformate was 0.068 percent. The composition underwent the initial 15 minute cure under the "1st activating light." The apparatus was substantially the same as described for the above Example 1, with the following exceptions:

1. The air flowrate on each side of the lens mold assembly was estimated to be about 18-20 cubic feet per minute.

2. The air flowrate in and out of the chamber surrounding the lights was varied in accordance with the surface temperature of the lights. The air flowrate was varied in an effort to keep the temperature on the surface of one of the lights between 104.5 ° F and 105 ° F.

3. The activating light output was controlled to a set point by varying the power sent to the lights as the output of the lights varied.

4. Frosted glass was placed between the lights and the filters used to vary the intensity of the activating light across the face of the molds. Preferably the glass was frosted on both sides. The frosted glass acts as a diffuser between the lights and these filters. This frosted glass tended to yield better results if it was placed at least about 2 mm from the filter, more preferably about 10-15 mm, more preferably still about 12 mm, from the filter. Frosted glass was found to dampen the effect of the filters. For instance, the presence of the frosted glass reduced the systems' ability to produce different lens powers by varying the light (see Example 1 and Figure 1).

After initial cure, the lens mold assembly was removed from the curing chamber. The lens mold assembly included a lens surrounded by a front mold, a back mold, and a gasket between the front and back molds (see, e.g., the assembly in Figure 11).

At this point the protocol in Example 1 stated that the lens was demolded (see above). While demolding at this point is possible, as stated above, generally some liquid lens forming composition remained, especially in areas of the lens proximate the gasket. Therefore, the lens was not demolded as stated in Example 1. Instead, the gasket was removed, liquid lens forming composition was wiped off the edges of the lens, and a layer of oxygen barrier (Parafilm M) with photoinitiator was wrapped around the edges of the lens while the lens was still between the molds. The Parafilm M was wrapped tightly around the edges of the lens and then stretched so that it would adhere to the lens and molds (i.e., in a manner similar to that of Saran wrap). The lens mold assembly was then placed in the post-cure unit so that the back face of the lens (while between the molds) could then be exposed to additional activating light.

This second activating light was at a substantially higher intensity than the initial cure light, which was directed at an intensity of less than 10 mW/cm^2. The mold assembly was irradiated with ultraviolet light for about 22 seconds. The total light energy applied during these 22 seconds was about 4500 millijoules per square centimeter ("mJ/cm^2").

It has been found that applying activating light at this point helped to cure some or all of the remaining liquid lens forming composition. The second activating light step may be repeated. In this example, the second activating light step was repeated once. It is also possible to expose the front or both sides of the lens to the second activating light.

After the second activating light was applied, the mold assembly was allowed to cool. The reactions caused by exposure to activating light may be exothermic. The

activating lights also tend to emit infra-red light which in turn heats the mold assembly. The lens was then demolded. The demolded lens was substantially drier and harder than lenses that were directly removed from mold assemblies after the initial cure step.

EXAMPLE 3: Oxygen Barrier Example #2

The protocol of Oxygen Barrier Example #1 was repeated except that prior to removal of the gasket the lens mold assembly was positioned so that the back face of the lens was exposed to third activating light. In this case the third activating light was at the same intensity and for the same time period as one pass of the second activating light. It has been found that applying third activating light at this point helped to cure some or all of the remaining liquid lens forming composition so that when the gasket was removed less liquid lens forming composition was present. All of the remaining steps in Oxygen Barrier Example #1 were applied, and the resultant lens was substantially dry when removed from the molds.

EXAMPLE 4: Conductive Heating Example

A liquid lens forming composition was initially cured in a process and apparatus similar to that specified in Example 1 except for post-cure treatment, which was conducted as follows:

After the sample was irradiated for 15 minutes, the lens was placed in the post-cure unit to receive a dose of about 1500 mJ/cm^2 (+/- 100 mJ) of activating light per pass. The gasket was then removed from the mold assembly and the edges of the mold were wiped with an absorbent tissue to remove incompletely cured lens forming material proximate the mold edges. A strip of plastic material impregnated with photoinitiator was wrapped around the edges of the molds that were exposed when the gasket was removed. Next, the mold assembly was passed through the post-cure unit once to expose

the front surface of the mold to a dose of about 1500 mJ/cm^2. The mold assembly was then passed through the post-cure unit four more times, with the back surface of the mold receiving a dose of about 1500mJ/cm^2 per pass. The heat source of the post-cure unit was operated such that the surface of the hot plate reached a temperature of 340 °F (+/- 50 °F). A conformable "beanbag" container having a covering made of NOMEX fabric was placed on the hot plate. The container contained glass beads and was turned over such that the portion of the container that had directly contacted the hot plate (i.e., the hottest portion of the container) faced upward and away from the hot plate. The mold assembly was then placed onto the heated, exposed portion of the container that had been in direct contact with the hot plate. The concave, non-casting face of the mold was placed onto the exposed surface of the container, which substantially conformed to the shape of the face. Heat was conducted through the container and the mold member to the lens for 13 minutes. A lens having a Shore D hardness of 84 was formed.

EXAMPLE 5: Curing Cycles

Some established cycles are detailed in Table 7 below for three semi-finished mold gasket sets: a 6.00D base curve, a 4.50D base curve, and a 3.00D base curve. These cycles have been performed with cooling air, at a temperature of about 56 °F, directed at the front and back surfaces of a mold assembly. Frosted diffusing window glass was positioned between the samples and the lamps, with a layer of PO-4 acrylic material approximately 1 inch below the glass. A top light intensity was adjusted to 760 microwatts/cm^2 and a bottom light intensity was adjusted to 950 microwatts/cm^2, as measured at about the plane of the sample. A Spectroline meter DM365N and standard detector stage were used. An in-mold coating as described in U.S. Patent No. 5,529,728 to Buazza et. al. was used to coat both the front and back molds.

		BASE CURVE	
Mold Sets	6.00	4.50	3.00
Front Mold	5.95	4.45	2.93
Back Mold	6.05	6.80	7.80
Gasket	-5.00	13 mm	16 mm
Resulting Semifinished Blank			
Diameter	74 mm	76 mm	76 mm
Center Thickness	9.0 mm	7.8 mm	7.3 mm
Edge Thickness	9.0 mm	11.0 mm	15.0 mm
Mass	46 grams	48 grams	57 grams
Curing Cycle Variables			
Total Cycle Time	25:00	25:00	35:00
Initial Exposure	4:40	4:40	4:35
Number of Pulses	4	4	4
Timing (in seconds) and Duration of Pulses @ Elapsed Time From Onset of Initial Exposure			
Pulse 1	15@10:00	15@10:00	15@13:00
Pulse 2	15@15:00	15@15:00	15@21:00
Pulse 3	30@19:00	30@19:00	20@27:00
Pulse 4	30@22:00	30@22:00	30@32:00

Table 7

Figures 26, 27, and 28 each show temperature profiles of the above-detailed cycles for a case where the activating light exposure is continuous and a case where the activating light delivery is pulsed. In Figures 26-28, "Io" denotes the initial intensity of the activating light used in a curing cycle. The phrase "Io=760/950" means that the light intensity was adjusted to initial settings of 760 microwatts/cm^2 for the top lamps and 950 microwatts/cm^2 for the bottom lamps. The "interior temperature" of Figures 26-28 refers to a temperature of the lens forming material as measured by a thermocouple located within the mold cavity.

EXAMPLE 6: Pulse Method Using a Medium Pressure Vapor Lamp

An eyeglass lens was successfully cured with activating light utilizing a medium pressure mercury vapor lamp as a source of activating light (i.e., the UVEXS Model 912 previously described herein). The curing chamber included a six inch medium pressure vapor lamp operating at a power level of approximately 250 watts per inch and a defocused dichroic reflector that is highly activating light reflective. A high percentage of infrared radiation was passed through the body of the reflector so that it would not be directed toward the material to be cured. The curing chamber further included a conveyer mechanism for transporting the sample underneath the lamp. With this curing chamber, the transport mechanism was set up so that a carriage would move the sample from the front of the chamber to the rear such that the sample would move completely through an irradiation zone under the lamp. The sample would then be transported through the zone again to the front of the chamber. In this manner the sample was provided with two distinct exposures per cycle. One pass, as defined hereinafter, consists of two of these distinct exposures. One pass provided a dosage of approximately 275 milliJoules measured at the plane of the sample using an International Light IL 1400 radiometer equipped with a XRL 340 B detector.

A lens cavity was created using the same molds, lens forming composition, and gasket as described in Example 7 below. The reaction cell containing the lens forming material was placed on a supporting stage such that the plane of the edges of the convex mold were at a distance of approximately 75 mm from the plane of the lamp. The lens cavity was then exposed to a series of activating light doses consisting of two passes directed to the back surface of the mold followed immediately by one pass directed to the front surface of the mold. Subsequent to these first exposures, the reaction cell was allowed to cool for 5 minutes in the absence of any activating radiation at an air temperature of 74.6 degrees F and at an air flow rate of approximately 15 to 25 scf per minute to the back surface and 15 to 25 scf to the front surface of the cell. The lens cavity was then dosed with one pass to the front mold surface and returned to the cooling chamber for 6 minutes. Then the back surface was exposed in one pass and then was

cooled for 2 minutes. Next, the front surface was exposed in two passes and then cooled for 3.5 minutes. The front surface and the back surface were then each exposed to two passes, and the gasket was removed to expose the edges of the lens. A strip of polyethylene film impregnated with photoinitiator was then wrapped around the edge of the lens and the front and back surfaces were exposed to another 3 passes each. The back surface of the cell was then placed on the conductive thermal in-mold postcure device using a "bean-bag" container filled with glass beads on a hot plate at about 340 °F described previously (see Example 4) for a time period of 13 minutes, after which the glass molds were removed from the finished lens. The finished lens exhibited a distance focusing power of -6.09 diopters, had excellent optics, was aberration-free, was 74 mm in diameter, and had a center thickness of 1.6 mm. During the cooling steps , a small surface probe thermistor was positioned against the outside of the gasket wall to monitor the reaction. The results are summarized below.

Activating Light Dose	Approx. Elapsed Time After Activating Light Dose (min)	Gasket Wall Temperature (° F)
2 passes to back surface and 1 pass to front surface	0	Not recorded
	1	80.5
	2	79.7
	3	79.0
	4	77.1
	5	76.2
1 pass to front surface	0	Not recorded
	1	83.4
	2	86.5
	3	84.6
	4	Not recorded
	5	81.4
	6	79.5
1 pass to back surface	0	Not recorded
	1	79.3
	2	79.0
2 passes to front surface	0	Not recorded
	1	78.4
	2	77.8
	3	77.0

	3.5	76.7

EXAMPE 7: Pulse Method Using a Single Xenon Flash Lamp

An eyeglass lens was successfully cured with activating light utilizing a xenon flash lamp as a source of activating light. The flash lamp used was an Ultra 1800 White Lightning photographic strobe, commercially available from Paul C. Buff Incorporated of Nashville, Tennessee. This lamp was modified by replacing the standard borosilicate flash tubes with quartz flash tubes. A quartz flash tube is preferred because some of the activating light generated by the arc inside the tube tends to be absorbed by borosilicate glass. The strobe possessed two semicircular flash tubes that trigger simultaneously and the flash tubes were positioned to form a ring approximately 73 millimeters in diameter. The hole in the reflector behind the lamps, which normally contains a modeling lamp for photographic purposes, was covered with a flat piece of highly-polished activating light reflective material that is commercially available under the trade name of Alzac from Ultra Violet Process Supply of Chicago, Illinois. The power selector switch was set to full power. The activating light energy generated from one flash was measured using an International Light IL 1700 Research Radiometer available from International Light, Incorporated of Newburyport, Massachusetts. The detector head was an International Light XRL 340 B, which is sensitive to radiation in the 326 nm to 401 nm region. The window of the detector head was positioned approximately 35 mm from the plane of the flash tubes and was approximately centered within the ring formed by the tubes.

A mold cavity was created by placing two round 80 mm diameter crown glass molds into a silicone rubber ring or gasket that possessed a raised lip around its inner circumference. The edges of the glass molds rested upon the raised lip to form a sealed cavity in the shape of the lens to be created. The inner circumference of the raised lip corresponded to the edge of the finished lens. The concave surface of the first mold corresponded to the front surface of the finished lens and the convex surface of the second mold corresponded to the back surface of the finished lens. The height of the raised lip of the rubber ring into which the two glass molds are inserted controls the

spacing between the two glass molds, thereby controlling the thickness of the finished lens. By selecting proper gaskets and first and second molds that possess various radii of curvature, lens cavities may be created to produce lenses of various powers.

A lens cavity was created by placing a concave glass mold with a radius of curvature of 407.20 mm and a convex glass mold with a radius of curvature of 65.26 mm into a gasket which provided spacing between the molds of 1.8 mm measured at the center of the cavity. Approximately 32 grams of a lens forming monomer was charged into the cavity. The lens forming material used for this test was OMB-91 lens monomer. The reaction cell containing the lens forming material was placed horizontally on a supporting stage such that the plane of the edges of the convex mold were at a distance of approximately 30 mm from the plane of the flash tubes and the cell was approximately centered under the light source.

The back surface of the lens cavity was then exposed to a first series of 5 flashes, with an interval of approximately 4 seconds in between each flash. The cell was then turned over and the front surface was exposed to another 4 flashes with intervals of about 4 seconds in between each flash. It is preferable to apply the first set of flashes to the back surface to start to cure the material so that any air bubbles in the liquid monomer will not migrate from the edge of the cavity to the center of the optical zone of the lens. Subsequent to these first nine flashes, the reaction cell was allowed to cool for five minutes in the absence of any activating radiation. To cool the reaction cell, air at a temperature of 71.4 degrees F and at a flow rate of approximately 15 to 25 scf per minute was applied to the back surface and air at a temperature of 71.4 degrees F and at a flow rate of approximately 15 to 25 scf per minute was applied to the front surface of the cell. The back surface of the lens cavity was then dosed with one more flash and returned to the cooling chamber for four minutes.

Next, the cell was exposed to one flash on the front surface and cooled in the cooling chamber for seven minutes. Then the cell was exposed to one flash on the front surface and one flash on the back surface and cooled for three minutes. Next, the cell was exposed to two flashes on the front surface and two flashes on the back surface and cooled for four and a half minutes. The cell was then exposed to five flashes each to the back surface and front surface, and the gasket was removed to expose the edges of the lens. A strip of polyethylene film impregnated with photoinitiator (Irgacure 184) was then wrapped around the edge of the lens, and the cell was exposed to another five flashes to the front surface and fifteen flashes to the back surface. The back surface of the cell was then placed on the conductive thermal in-mold postcure device (i.e., "bean bags" filled with glass beads sitting on a hot plate at approx. 340 ° F) as described previously (see conductive heating example above) for a time period of 13 minutes, after which the glass molds were removed from the finished lens. The finished lens exhibited a distance focusing power of -6.16 diopters and a +2.55 bifocal add power, had excellent optics, was aberration-free, was 74 mm in diameter, and had a center of thickness of 1.7 mm. During the cooling steps , a small surface probe thermistor was positioned against the outside of the gasket wall to monitor the reaction. The results are summarized below.

Dose	Elapsed Time From Dose (min)	Gasket Wall Temperature (F)
5 flashes to back surface and 4 flashes to front surface	0	Not recorded
	1	Not recorded
	2	78.4
	3	77.9
	4	76.9
	5	75.9
1 flash to back surface	0	Not recorded
	1	76.8
	2	77.8
	3	78
	4	77.8
1 flash to front surface	0	Not recorded
	1	79.4
	2	81.2
	3	81.1
	4	79.7
	5	78.7
	6	77.5
	7	77.4
1 flash to front surface and 1 flash to back surface	0	Not recorded
	1	78.8
	2	78.8
	3	78.0
2 flashes to front surface and 2 flashes to back surface	0	Not recorded
	1	80.2
	2	79.8
	3	78.3
	4	76.7
	4.5	76.3

EXAMPLE 8: Improved Curing Example

An 80 mm diameter glass progressive addition mold with a nominal distance radius of curvature of -6.00 diopters and a +2.50 diopter bifocal add power was sprayed with a mixture of isopropyl alcohol and distilled water in equal parts and wiped dry with a lint free paper towel. The progressive mold was lenticularized to provide an optical

zone 68 mm in diameter along the 180 degree meridian and 65 mm in diameter along the 90 degree meridian. The non-casting face of the mold was mounted to a suction cup, which was attached to a spindle. The spindle was placed on a spin coat unit. A one inch diameter pool of liquid Primer was dispensed into the center of the horizontally positioned glass mold from a soft polyethylene squeeze bottle equipped with a nozzle with an orifice diameter of approximately 0.040 inches. The composition of the Primer is discussed in detail below (see Scratch Resistant Lens Formation Process Example).

The spin motor was engaged to rotate the mold at a speed of approximately 850 to 900 revolutions per minute, which caused the liquid material to spread out over the face of the mold. Immediately thereafter, a steady stream of an additional 1.5 to 2.0 grams of Primer material was dispensed onto the casting face of the spinning mold with the nozzle tip positioned at a 45 degree angle approximately 12 mm from the mold face such that the stream was flowing with the direction of rotation of the mold. The stream of Primer material was directed first at the center of the mold face and then dispensed along the radius of the mold face in a direction from the center toward the edge of the mold face. The solvent present in the Primer was allowed to evaporate off for 8 to 10 seconds while the mold was rotated. The rotation was stopped and the Primer coat present on the mold was cured via two exposures to the activating light output from the medium pressure mercury vapor lamp, totaling approximately 300 mJ/cm^2.

The spin motor was again engaged and approximately 1.5 to 2.0 grams of HC8-H Hard Coat (see description below), commercially available from the FastCast Corporation of Louisville, Kentucky was dispensed onto the spinning mold in a similar fashion as the Primer coat. The solvent present in the HC8-H was allowed to evaporate off for 25 seconds while the mold was rotated. The rotation was stopped and the HC8-H coat was cured in the same manner as the Primer coat.

The mold was removed from the FlashCure unit and assembled into a silicone rubber gasket in combination with a cleaned convex mold possessing a radius of curvature of +2.00 diopters. The raised lip present on the inner circumference of the rubber gasket provided a spacing of 6.3 mm between the two molds at the center point. The mold/gasket assembly was positioned on a filling stage and the edge of the gasket was peeled back to permit the cavity to be filled with OMB-91 lens forming composition, commercially available from the FastCast Corporation of Louisville, Kentucky. The edge of the gasket was returned to its sealing relationship with the edges of the molds and the excess lens forming composition was vacuumed off the non-casting surface of the back mold with a suction device. The filled mold/gasket assembly was placed on a stage in a lens curing unit and subjected to four exposures of the activating light output from the six inch medium pressure mercury vapor lamp, totaling approximately 600 mJ/cm^2.

Immediately following this initial dose of high intensity activating light, the assembly was continuously exposed to streams of air having a temperature of 42 °F while being irradiated with very low intensity activating light for eight minutes. The light intensity measured approximately 90 microwatts/cm^2 from above plus approximately 95 microwatts/cm^2 from below, according to the plus lens light distribution pattern called for by the manufacturer. The lamp racks are typically configured to deliver activating light having an intensity of about 300 microwatt/cm^2 for the standard fifteen minute curing cycle. The reduction in activating light intensity was accomplished by inserting a translucent high density polyethylene plate into the light distribution filter plate slot along with the plus lens light distribution plate. A translucent high density polyethylene plate was positioned between the front mold member and one light distribution plate and between the back mold member and the other light distribution plate.

The non-casting surface of the back mold was subsequently exposed to four doses of high intensity activating light totaling approximately 1150 mJ/cm^2. The gasket was stripped from the assembly and residual uncured material wiped from the exposed edge

of the lens. An oxygen barrier strip (polyethylene) was wrapped around the edge of the lens and the mold was exposed to two more doses of high intensity activating light totaling 575 mJ/cm^2 to the non-casting surface of the front mold followed by eight more flashes to the non-casting surface of the back mold totaling 2300 mJ/cm^2.

The non-casting surface of the back mold was placed in contact with a thermal transfer pad, commercially available from the FastCast Corporation of Louisville, Kentucky, at a temperature of approximately 150 to 200 °F for thirteen minutes. The assembly was removed from the thermal transfer pad and the back mold was removed with a slight impact from an appropriately sized wedge. The front mold with the lens attached thereto was placed in a container of room temperature water and the lens separated from the front mold. The now-finished lens was sprayed with a mixture of isopropyl alcohol and water in equal parts and wiped dry. The lens read +3.98 D with an addition power of +2.50, was clear , non-yellow, and exhibited good optics.

EXAMPLE 9: Scratch Resistant Lens Formation Example

A first coating composition, hereinafter referred to as "Primer", was prepared by mixing the following components by weight:

93.87% acetone;

3.43% SR-399 (dipentaerythritol pentaacrylate), available from Sartomer;

2.14% CN-104 (epoxy acrylate), available from Sartomer;

0.28% Irgacure 184 (1-hydroxycyclohexylphenylketone), available from Ciba-Geigy; and

0.28% Darocur 1173 (2-hydroxy-2-methyl-1-phenyl-propan-1-one) available from Ciba-Geigy.

A second coating composition, hereinafter referred to as "HC8-H" was prepared by mixing the following components by weight:

84.69% 1-methoxy 2-propanol;

9.45% SR-399 (dipentaerythritol pentaacrylate), available from Sartomer;

4.32% SR601 (ethoxylated bisphenol A diacrylate), available from Sartomer; and

1.54% Irgacure 184 (1-hydroxycyclohexyl phenyl ketone), available from Ciba-Geigy.

Each of these coating compositions was prepared by first dissolving the monomers into the solvent, then adding the photoinitiators, mixing well, and finally passing the composition through a one micron filter prior to use.

An 80 mm diameter glass, 28 mm flattop mold with a distance radius of curvature of -6.00 diopters and a +2.00 diopter bifocal add power were sprayed with a mixture of isopropyl alcohol and distilled water in equal parts. The flattop mold was wiped dry with a lint free paper towel. The non-casting face of the mold was mounted to a suction cup, which was attached to a spindle. The spindle was placed on the spin coating unit.

A one inch diameter pool of liquid Primer was dispensed into the center of the horizontally positioned glass mold. The Primer was dispensed from a soft polyethylene squeeze bottle equipped with a nozzle having an orifice diameter of approximately 0.040 inches. A spin motor of the spinning device was engaged to rotate the mold at a speed of approximately 850 to 900 revolutions per minute, causing the liquid Primer to spread out over the face of the mold. Immediately thereafter, a steady stream of an additional 1.5 to 2.0 grams of Primer material was dispensed onto the casting face of the spinning mold. The stream of Primer material was directed onto the casting face with the nozzle tip positioned at a 45 degree angle approximately 12 mm from the mold face. This positioning of the nozzle tip made the stream to flow with the direction of rotation of the mold. The stream of Primer material was directed first at the center of the mold face and then dispensed along the radius of the mold face in a direction from the center toward the edge of the mold face.

The solvent present in the Primer was allowed to evaporate off for 8 to 10 seconds during rotation of the mold. The rotation was stopped and the Primer coat which remained on the mold was cured via two exposures to the activating output from a medium pressure mercury vapor lamp, totaling approximately 300 mJ/cm^2. All light intensity/dosage measurements cited herein were taken with an International Light IL-1400 Radiometer equipped with an XLR-340B Detector Head, both commercially available from International Light, Inc. of Newburyport, Massachusetts.

Upon exposure to the activating light, the spin motor was again engaged and approximately 1.5 to 2.0 grams of HC8-H Hard Coat, commercially available from the FastCast Corporation of Louisville, Kentucky was dispensed onto the spinning mold in a similar fashion as the Primer coat. The solvent present in the HC8-H was allowed to evaporate off for 25 seconds while the mold was spinning. The rotation was stopped, and the HC8-H coat was cured in the same manner as the Primer coat.

The mold was removed from the spin coating unit and assembled into a silicone rubber gasket in combination with a cleaned convex mold possessing a radius of curvature of +7.50 diopters. The raised lip present on the inner circumference of the rubber gasket provided a spacing of 1.8 mm between the two molds at the center point. At this point, the mold/gasket assembly was positioned on a filling stage and the edge of the gasket was peeled back to permit the cavity to be filled with OMB-91 lens forming composition, commercially available from the FastCast Corporation of Louisville, Kentucky. The edge of the gasket was returned to its sealing relationship with the edges of the molds and the excess lens forming composition was vacuumed off the non-casting surface of the back mold with a suction device.

The filled mold/gasket assembly was transferred from the filling stage to a lens curing unit. While in the lens curing unit, the assembly was continuously irradiated with activating light from both sides for a period of 15 minutes at approximately 300

microwatts/cm^2 from above and at approximately 350 microwatts/cm^2 from below, according to the minus lens light distribution pattern called for by the manufacturer. During the irradiation, the casting cell was continuously exposed to streams of air having a temperature of 42 °F.

The non-casting surface of the back mold was exposed to four doses of high intensity activating light totaling approximately 1150 mJ/cm^2. The gasket was stripped from the assembly and residual uncured material was wiped from the exposed edge of the lens. An oxygen barrier strip (polyethylene) was wrapped around the edge of the lens. The mold/gasket assembly was exposed to two more doses of high intensity activating light, wherein 575 mJ/cm^2 total was directed to the non-casting surface of the front mold. Subsequently, eight more flashes of the activating light were directed to the non-casting surface of the back mold, totaling 2300 mJ/cm^2.

The non-casting surface of the back mold was placed in contact with a thermal transfer pad, commercially available from the FastCast Corporation of Louisville, Kentucky, at a temperature of approximately 150 to 200° F for thirteen minutes. The mold/gasket assembly was removed from the thermal transfer pad, and the back mold was removed with a slight impact from an appropriately sized wedge. The front mold with the lens attached thereto was placed in a container of room temperature water. While within the water, the lens became separated from the front mold. The now-finished lens was sprayed with a mixture of isopropyl alcohol and water in equal parts and wiped dry.

The lens was positioned in a holder and placed into a heated dye pot for 5 minutes. The dye pot contained a solution of BPI Black, commercially available from Brain Power, Inc. of Miami, Florida, and distilled water at a temperature of approximately 190 degrees F. The lens was removed from the dye pot, rinsed with tap water, and wiped dry. The lens exhibited a total visible light absorbance of approximately 80%. When inspected for cosmetic defects on a light table, no pinhole

defects were observed. Further, the tint which had been absorbed by the back surface of the lens was found to be smooth and even.

EXAMPLE 10: Formation of a Plastic Lens Containing Photochromic Material.

A polymerizable mixture of PRO-629 (see above for a description of the components of PRO-629), photochromic pigments, and a photoinitiator/co-initiator system was prepared according to the following procedure. A photochromic stock solution was prepared by dissolving the following pigments into 484 grams of HDDMA.

Pigment	grams	% by wt.
Dye #94	1.25	0.250%
Dye # 266	0.45	0.090%
Variacrol Red PNO	2.66	0.532%
Variacrol Yellow L	1.64	0.328%
Reversacol Corn Yellow	3.58	0.716%
Reversacol Berry Red	2.96	0.590%
Reversacol Sea Green	2.17	0.434%
Reversacol Palatinate Purple	1.29	0.258%
Total	16.0	3.200%

Dye #94 and Dye #266 are indilino-spiropyrans commercially available from Chroma Chemicals, Inc. in Dayton, Ohio. Variacrol Red PNO is a spiro-napthoxazine material and Variacrol Yellow L is a napthopyran material, both commercially available from Great Lakes Chemical in West Lafayette, Indiana. Reversacol Corn Yellow and Reversacol Berry Red are napthopyrans and Reversacol Sea Green, and Reversacol Palatinate Purple are spiro-napthoxazine materials commercially available from Keystone Analine Corporation in Chicago, Illinois.

The powdered pigments were weighed and placed in a beaker. The HDDMA was added to the powdered pigments, and the entire mixture was heated to a temperature in the range from about 50°C to 60°C and stirred for two hours. Subsequently, the photochromic stock solution was cooled to room temperature and then gravity fed through a four inch deep bed of aluminum oxide basic in a one inch diameter column. Prior to passing the stock solution through the alumina, the alumina was washed with acetone and dried with air. The remaining HDDMA was forced out of the alumina with pressurized air. It is believed that this filtration step removes any degradation by-products of the photochromic pigments and/or any impurities present in the mixture. After the filtration step, the stock solution was passed through a 1 micron filter to remove any alumina particles which may have passed out of the column with the stock solution.

A photoinitiator stock solution containing a photoinitiator combined with an ultraviolet/visible light absorber was also prepared by mixing 2.56 grams of CGI-819 and 0.2 grams of Tinuvin 400, an ultraviolet/visible light absorber commercially available from Ciba Additives of Tarrytown, New York, with 97.24 grams of PRO-629. The stock solution was stirred for two hours at room temperature in the absence of light. The photoinitiator stock solution was then filtered by passing it through a layer of alumina and a one micron filter. The stock solution was placed in an opaque polyethylene container for storage.

A background dye stock solution was prepared by mixing 50 grams of a 422 ppm solution of A241/HDDMA, 50 grams of a 592 ppm solution of Thermoplast Red 454/HDDMA, 50 grams of 490 ppm solution of Zapon Brown 286/HDDMA, 50 grams of 450 ppm solution of Zapon Brown 287/HDDMA, 50 grams of 1110 ppm solution of Oil Soluble Blue II/HDDMA, and 50 grams of a 1110 ppm solution of Thermoplast Blue P/HDDMA, all with 700 grams of PRO-629. The entire mixture was heated to a temperature ranging from about 50°C to 60°C and subsequently stirred for two hours.

A lens forming composition was prepared by adding 12.48 grams of the above described photochromic stock solution, 10 grams of the photoinitiator stock solution, 27 grams of the background dye stock solution, and 7.3 grams of the NMDEA co-initiator to 943.22 grams of PRO-629. The components of the lens forming composition were stirred at room temperature for several minutes until well mixed. This composition is hereafter referred to as PC #1. The PC#1 contained the following amounts of components.

Component	Amount
Tripropyleneglycol diacrylate	31.16 %
Tetraethyleneglycol diacrylate	20.45 %
Trimethylolpropane triacrylate	19.47 %
Bisphenol A bis allyl carbonate	16.55 %
Hexanediol dimethacrylate	11.56 %
Dye #94	31.20 ppm
Dye # 266	11.20 ppm
Variacrol Red PNO	66.40 ppm
Variacrol Yellow L	40.90 ppm
Reversacol Corn Yellow	89.30 ppm
Reversacol Berry Red	73.60 ppm
Reversacol Sea Green	54.20 ppm
Reversacol Palatinate Purple	32.20 ppm
A241	0.57 ppm
Thermoplast Red 454	0.80 ppm
Zapon Brown 286	0.66 ppm
Zapon Brown 287	0.61 ppm
Oil Soluble Blue II	1.50 ppm
Thermoplast Blue	1.50 ppm
CGI-819	255.90 ppm

NMDEA	0.73 %
Tinuvin 400	20.00 ppm

An 80mm diameter concave glass progressive addition mold having a distance radius of curvature of 6.00 diopters and a +1.75 diopter bifocal add power was sprayed with a mixture of isopropyl alcohol and distilled water in equal parts and wiped dry with a lint free paper towel. The mold was then mounted with its casting face upward on the center of a stage. The mold was fixed securely to the stage using three equidistant clip-style contact points to hold the periphery of the mold. The mold stage had a spindle attached to it which was adapted to connect to a spin coating device. The mold stage, with the mold affixed, was placed within the spin coating device. The mold was rotated at approximately 750 to 900 revolutions per minute. A stream of isopropyl alcohol was directed at the casting surface while the casting surface was simultaneously brushed with a soft camel hair brush to clean the surface. After the cleaning step, the mold surface was dried by directing a stream of reagent grade acetone over the surface and allowing it to evaporate off, all while continuing the rotation of the mold.

The rotation of the mold was then terminated and a one inch diameter pool of a liquid coating composition was dispensed into the center of the horizontally positioned glass mold from a soft polyethylene squeeze bottle equipped with a nozzle having an orifice diameter of approximately 0.040 inches. The spin motor was engaged to rotate the mold at a speed of approximately 750 to 900 revolutions per minute, causing the liquid material to spread out over the face of the mold. Immediately thereafter, a steady stream of an additional 1.5 to 2.0 grams of the coating composition was dispensed onto the casting face of the spinning mold. The stream was moved from the center to the edge of the casting face with a nozzle tip positioned at a 45° angle approximately 12 mm from the mold face. Thus, the stream was flowing with the direction of rotation of the mold.

The solvent present in the coating composition was allowed to evaporate while rotating the mold for 10 to 15 seconds. The rotation was stopped, and then the coating composition on the mold was cured via a total exposure of approximately 300 mJ/cm^2 of activating light. The light was provided from a medium pressure mercury vapor lamp. All light intensity/dosage measurements cited herein were taken with an International Light IL-1400 Radiometer equipped with an XLR-340B Detector Head, both commercially available from International Light, Inc. of Newburyport, Massachusetts. At this point, the spin motor was again engaged and approximately 1.5 to 2.0 grams of additional coating composition was dispensed onto the spinning mold. The solvent of the composition was allowed to evaporate, and the composition was cured in a similar fashion to the first layer of coating composition.

The above described coating composition comprised the following materials:

Material	% by wt.
Irgacure 184	0.91 %
Tinuvin 770	0.80 %
CN-104	2.00 %
SR-601	1.00 %
SR-399	8.60 %
Acetone	26.00 %
Ethanol	7.00 %
1-Methoxypropanol	53.69 %

Irgacure 184 is a photoinitiator commercially available from Ciba Additives, Inc. CN-104 is an epoxy acrylate oligomer, SR-601 is an ethoxylated bisphenol A diacrylate, and SR-399 is dipentaerythritol pentaacrylate, all available from Sartomer Company in Exton, Pennsylvania. The acetone, the ethanol, and the 1-methoxypropanol were all

reagent grade solvents. The Tinuvin 770 improves the impact resistance of the lens and is available from Ciba Additives, Inc.

An 80 mm diameter convex mold with radii of curvature of 6.80/7.80 diopters was cleaned and coated using the same procedure described above except that no pooling of the coating composition occurred in the center of the mold when the composition was dispensed thereto.

The concave and convex molds were then assembled together with a silicone rubber gasket. A raised lip on the inner circumference of the rubber gasket provided a spacing of 2.8 mm between the two molds at the center point. At this point the mold/gasket assembly was positioned on a filling stage. The edge of the gasket was peeled back to permit the cavity to be filled with PC #1 lens forming composition. The edge of the gasket was returned to its sealing relationship with the edges of the molds, and the excess lens forming composition was vacuumed from the non-casting surface of the back mold with a suction device. The filled mold/gasket assembly was then transferred from the filling stage to a lens curing unit. The assembly was placed with the back mold facing upward on a black stage configured to hold the mold/gasket assembly.

An activating light filter was then placed on top of the back mold. The filter was approximately 80 mm in diameter which is the same as the mold diameter. The filter also had a spherical configuration with a center thickness of 6.7 mm and an edge thickness of 5.5 mm. The filter was taken from a group of previously made filters. These filters were formed by using eyeglass lens casting molds and gaskets to create cavities that were thickest in the center (a plus spherical cavity) and cavities that were thinnest in the center (a minus spherical cavity). A toric component was also incorporated with some of these cavities to form compound cavities.

The filter cavities were filled with an activating light curable composition comprising by weight: 99.37% PRO-629, 0.35 % K-Resin, 0.27% NMDEA, 121 ppm CGI-819, and 10 ppm Tinuvin 400. K-resin is a styrene-butadiene copolymer commercially available from Phillips Chemical Company. To form this composition, the K-resin was first dissolved in toluene. An appropriate amount of the K-resin toluene solution was added to the PRO-629, and then the toluene was evaporated off by heat and stirring. The NMDEA, CGI-819, and the Tinuvin 400 were then added to the PRO-629/K-Resin solution. The compositions contained in the cavities were cured by exposure to activating light. When the cured article was removed from the mold cavity, it exhibited a high degree of haze caused by the incompatibility of the PRO-629. and the K-Resin. In the strictest sense of the word, it should be noted that these filters were not "lenses" because their function was not to focus light but rather to scatter and diffuse light.

The mold/gasket assembly and the filter were then irradiated with four consecutive doses of activating light totaling approximately 1150 mJ/cm^2, as previously measured at the plane of the mold cavity with no filter or any other intervening media between the light source and the plane. The mold/gasket assembly was then turned over on the stage so that the front mold was facing upward. The mold/gasket assembly was further rotated 90 degrees around the paraxial axis from its original position. The light filter was then placed over the front mold. The entire assembly was then exposed to two more doses of activating light totaling approximately 575 mJ/cm^2. The mold/gasket assembly was removed from the curing chamber. The gasket was removed from the molds, and the exposed edge of the lens was wiped to remove any residual liquid. The molds with lens were then placed in a vertical orientation in a rack, and the non-casting faces of both the front and back molds were exposed to ambient room temperature air for a period of approximately ten minutes. Then, without the aforementioned light filter in place, the mold assembly was dosed with four exposures totaling 600 mJ/cm^2 directed

toward the back mold and two exposures totaling 300 mJ/cm^2 directed toward the front mold.

Subsequent to these exposures, the junction of the back mold and the lens was scored with the edge of a brass spatula. The back mold was then removed from the lens by positioning an appropriate sized Delrin wedge between the front and back molds and applying a sharp impact to the wedge. The lens, along with the front mold to which it was attached, was held under running tap water and simultaneously brushed with a soft brush to remove any flakes or particles of polymer from the edges and surface of the lens. The front mold was then separated from the lens by breaking the seal between the two with the point of a pin pressed against the junction of the front mold and the lens. The lens was then placed concave side upward on a lens stage of similar design to the mold stage, except that the peripheral clips were configured to secure a smaller diameter workpiece. The lens stage, with the lens affixed, was positioned on the spin coating unit and rotated at about 750 to 900 revolutions per minute. A stream of isopropyl alcohol was directed at the concave surface while simultaneously brushing the surface with a soft, clean brush.

After brushing, a stream of isopropyl alcohol was directed at the surface of the lens, and the rotation was continued for a period of approximately 30 seconds until the lens was dry. The lens was turned over on the stage so that the convex surface of the lens faced upward. Then the cleaning procedure was repeated on the convex surface. With the convex surface facing upward, the lens was dosed with four exposures of activating light totaling approximately 1150 mJ/cm^2. The lens was again turned over on the stage such that the concave surface was upward. The lens was subjected to an additional two exposures totaling 300 mJ/cm^2. The lens was removed from the stage and placed in a convection oven at 115°C for five minutes. After annealing the lens, it was removed from the oven and allowed to cool to room temperature. At this point the lens was ready for shaping by conventional means to fit into an eyeglass frame.

The resulting lens was approximately 72 mm in diameter. The lens had a center thickness of 2.6 mm, a distance focusing power of –0.71 –1.00 diopters, and a bifocal addition strength of 1.74 diopters. The lens appeared to have a bleached color of tan. Also, the lens that was formed exhibited approximately 75 % visible transmittance as measured with a Hoya ULT-3000 meter. The lens was exposed to midday sunlight at a temperature of approximately 75 ° F for 3 minutes. After being exposed to sunlight, the lens exhibited a gray color and a visible light transmittance of approximately 15 %. The optics of the lens appeared to be crisp, without aberrations in either the distance or the bifocal segment regions. The same lens forming composition was cured to form a plano lens so that the lens could be scanned with a Hewlett Packard Model 8453 UV-Vis spectrophotometer. See Fig. 30 for a plot of % transmittance versus wavelength (nm), as exhibited by the plano lens in its lightened state (i.e., without sunlight exposure). The lens exhibited very little transmittance of light at wavelengths below about 370 nm.

The eyeglass lens of this example was formed from a lens forming composition included ultraviolet/visible light absorbing photochromic compounds by using activating light. Since photochromic pigments tend to absorb ultraviolet/visible light strongly, the activating light might not have penetrated to the depths of the lens forming composition. The lens forming composition, however, contained a co-initiator in conjunction with a photoinitiator to help promote the curing of the entire lens forming composition. The present example thus demonstrates that a photochromic lens containing both a photoinitiator and a co-initiator may be cured using activating light to initiate polymerization of the lens forming composition.

<u>EXAMPLE 11: Casting a Colorless Lens Containing Ultraviolet/Visible Light Absorbers</u>

According to a preferred embodiment, a polymerizable mixture of PRO-629 (see above for a description of the components of PRO-629), colorless ultraviolet/visible light

absorbing compounds, an ultraviolet stabilizer, background dyes, and a photoinitiator/co-initiator package was prepared according to the following procedure. Six separate stock solutions were prepared. One stock solution contained the photoinitiator, two stock solutions contained ultraviolet/visible light absorbing compounds, one stock solution contained co-initiators, one stock solution contained an ultraviolet light stabilizer, and one stock solution contained a background dye package. Each of these stock solutions were treated by passing them through a one inch diameter column packed with approximately 30 grams of alumina basic. It is believed that this step reduced the impurities and trapped the acidic byproducts present in each of the additives to the PRO-629. The following is a detailed description of the preparation of the polymerizable mixture mentioned above.

About 500 grams of a photoinitiator stock solution was prepared by dissolving 2.5% by weight of phenyl bis(2,4,6-trimethylbenzoyl) phosphine oxide (CGI-819 commercially available from Ciba Additives) in Pro-629. This mixture was passed through an alumina basic column in the dark.

About 500 grams of the ultraviolet light absorber stock solution was prepared by dissolving 2.5% by weight of 2(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethyl)phenol (98% purity) in PRO-629. This mixture was also passed through an alumina basic column.

About 500 grams of a co-initiator stock solution was prepared by mixing 70% by weight of CN-384 (a reactive amine co-initiator commercially available from Sartomer Company) in Pro- 629. This mixture was passed through an alumina basic column.

About 271 grams of an ultraviolet light stabilizer stock solution was prepared by mixing 5.55% by weight of Tinuvin 292 in PRO-629. This mixture was passed through an alumina basic column.

About 250 grams of an ultraviolet/visible light absorber stock solution was prepared by mixing 5.0% Tinuvin 400 (a mixture of 2-[4-((2-hydroxy-3-dodecyloxypropyl)-oxy)-2-hydroxyphenyl]-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine and 2-[4-((2-hydroxy-3-tridecyloxypropyl)-oxy)-2-hydroxyphenyl]-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine) by weight in PRO-629. This mixture was passed through an alumina basic column.

About 1000 grams of a background dye stock solution was prepared by mixing about 50 grams of a 592 ppm solution of Thermoplast Red 454/HDDMA, 50 grams of 490 ppm solution of Zapon Brown 286/HDDMA, 50 grams of 450 ppm solution of Zapon Brown 287/HDDMA, 50 grams of 1110 ppm solution of Oil Soluble Blue II/HDDMA, and 50 grams of a 1110 ppm solution of Thermoplast Blue P/HDDMA, all with 750 grams of PRO-629. The entire mixture was heated to a temperature between about 50° and 60° C and stirred for two hours. This mixture was passed through an alumina basic column.

About 250 grams of CN-386 (a reactive amine co-initiator commercially available from Sartomer Company) was passed through an alumina basic column.

A lens forming composition was prepared by mixing 967.75 grams of PRO-629 with 12.84 grams of the 2.5% 2(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethyl)phenol ultraviolet/visible light absorber stock solution, 4.3 grams of the 70% CN-384 co-initiator stock solution, 8.16 grams of the 2.5% CGI-819 photoinitiator stock solution, 0.53 grams of the CN-386, 1.54 grams of the Tinuvin 400 ultraviolet/visible light absorber stock solution, 0.92 grams of the Tinuvin 292 ultraviolet light stabilizer stock solution, and 4.0 grams of the background dye stock solution. The resulting lens forming composition contained the following components:

Material	% by weight
PRO-629	99.10%
2(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethyl)phenol	321 ppm
Tinuvin 400	77 ppm
Tinuvin 292	51 ppm
CN-384	0.3%
CN-386	0.53%
CGI-819	204 ppm
Thermoplast Red	0.12 ppm
Zapon Brown 286	0.10 ppm
Zapon Brown 287	0.10 ppm
Oil Soluble Blue II	0.22 ppm
Thermoplast Blue	0.22 ppm

An 80mm diameter flattop concave glass mold with a distance radius of curvature of 2.85 diopters and a +3.00 diopter bifocal add power was cleaned and coated as described in Example 10.

An 80 mm diameter convex mold with radii of curvature of 7.05 diopters was cleaned and coated in the same fashion described above except that no pooling of the coating composition occurred in the center of the mold when the composition was dispensed thereto.

Both the concave and convex molds were then provided with a cured adhesion-promoting coating composition. By providing such a coating, the adhesion between the casting surface of the glass mold and the lens forming composition was increased, thereby reducing the possibility of premature release of the lens from the mold. The

coating further provided abrasion resistance, chemical resistance, and improved cosmetics to the finished lens.

The concave and convex molds were then assembled and placed within a lens curing unit as described in Example 10.

An activating light filter was then placed on top of the back mold. The filter was approximately 80 mm in diameter which is the same as the mold diameter. It had a plano configuration with a thickness of 3.1 mm. This filter transmitted approximately 30% of the incident activating light from the source as measured using the IL1400 radiometer with a XRL-340B detector head. The filter was taken from a group of previously made filters. The fabrication of these filters was discussed in Example 10.

The mold/gasket assembly in which the lens forming composition had been placed and which had been covered by the above described filter was then irradiated with four consecutive doses of activating light totaling approximately 600 mJ/cm^2, as measured using the IL-1400 Radiometer equipped with the XLR-340B detector. This measurement was taken at the plane of the mold cavity while no filter or any intervening media was present between the light source and the plane. The mold/gasket assembly was then turned over on the stage so that the front mold was facing upward. The mold/gasket assembly was further rotated 90 degrees around the paraxial axis from its original position. The light filter was then replaced over the front mold. The entire assembly was exposed to two more doses of activating light totaling approximately 300 mJ/cm^2.

The mold/gasket assembly was then removed from the curing chamber, and the gasket was removed from the assembly. The mold was then returned to the lens curing chamber such that the back mold was facing upward. An opaque rubber disc, approximately 80 mm in diameter was placed over the back mold. This disc had the function of preventing activating light from impinging on the major portion of the

material contained within the cavity. With the disc in position, the cell was exposed to two more exposures at 300 mJ/ cm^2. This subsequent exposure was used to cure the residual liquid around the edges of the lens, particularly around the junction between the front mold and the lens and to help seal the periphery. The mold assembly was removed from the curing chamber and placed in a vertical orientation in a rack. The non-casting faces of both the front and back molds were then exposed to ambient room temperature air for a period of approximately fifteen minutes. At this point, the entire mold assembly was dosed with two exposures totaling 300 mJ/cm^2 directed toward the back mold and two exposures totaling 300 mJ/cm^2 directed toward the front mold, without the aforementioned light filter or opaque disc in place.

The lens was removed from the mold assembly and post-cured as described in Example 10.

The resulting lens was approximately 72 mm in diameter, had a center thickness of 1.5 mm, a distance focusing power of –4.08 diopters, and a bifocal addition strength of 3.00 diopters. The resultant lens was water white. The optics of the lens were crisp, without aberrations in either the distance or the bifocal segment regions. The same lens forming composition was cured to form a plano lens. The plano lens was scanned with a Hewlett Packard Model 8453 UV-Vis spectrophotometer. See Fig. 31 for a plot of % transmittance versus wavelength (nm), as exhibited by the photochromic lens when exposed to sunlight. The lens exhibited virtually no transmittance of light at wavelengths below about 370 nm. Also shown in Fig. 31 are the results of a similar scan made on a plano lens formed using the OMB-91 lens forming composition (see Curing by the Application of Pulsed Activating Light above for components of OMB-91). The OMB-91 lens, which has no ultraviolet/visible light absorbing compounds, appears to transmit light at wavelengths shorter than 370 nm, unlike the colorless lens that contained ultraviolet/visible light absorbing compounds.

The eyeglass lens of this example was cured using activating light even though the lens forming composition included activating light absorbing compounds. Since activating light absorbing compounds tend to absorb activating light strongly, the activating light might not have penetrated to the depths of the lens forming composition. The lens forming composition, however, contained a co-initiator in conjunction with a photoinitiator to help promote the curing of the entire lens forming composition. The present example thus demonstrates that a lens containing ultraviolet/visible light absorbing compounds may be cured using activating light to initiate polymerization of a lens forming composition which contains a photoinitiator/co-initiator system. The lens was also produced using activating light of comparable intensity and duration as was used for the production of photochromic lenses. Thus, the addition of ultraviolet/visible light absorbers to a non-photochromic lens forming composition, allows both photochromic and non-photochromic lens forming compositions to be cured using the same apparatus and similar procedures.

EXAMPLE 12: Casting a Colored Lens Containing Ultraviolet/Visible Light Absorbers

According to a preferred embodiment, a polymerizable mixture of PRO-629 (see above for a description of the components of PRO-629), fixed pigments, and a photoinitiator/co-initiator package was prepared according to the following procedure. Nine separate stock solutions were prepared. Seven of the stock solutions contained fixed pigments, one of the stock solutions contained an ultraviolet/visible light absorbing compound, and one of the stock solutions contained a photoinitiator. Each of these stock solutions were treated by passing them through a one inch diameter column packed with approximately 30 grams of alumina basic. It is believed that this step reduces the impurities and traps the acidic byproducts present in each of the additives to the PRO-629.

For each of the following fixed pigments, a stock solution was prepared by the following procedure. The pigments used were Thermoplast Red 454, Thermoplast Blue P, Oil Soluble Blue II, Zapon Green 936, Zapon Brown 286, Zapon Brown 287, and Thermoplast Yellow 284. One gram of each pigment was dissolved in 499 grams of HDDMA. Each mixture was heated to a temperature in the range of from about 50°C to about 60°C for approximately two hours. This mixture was passed through an alumina basic column. The alumina was then washed with 200 grams of HDDMA at a temperature of about 50°C to about 60°C followed by 300 grams of PRO-629 at a temperature of about 50°C to about 60°C. This washing step ensured that any pigments trapped in the alumina were washed into the stock solution. This resulted in stock solutions which contained a 0.1% concentration of each pigment in 29.97% PRO-629 and 69.93% HDDMA.

About 250 grams of the ultraviolet/visible light absorber stock solution was prepared by dissolving 5.0% Tinuvin 400 by weight in PRO-629. This mixture was passed through an alumina basic column.

About 500 grams of the photoinitiator stock solution was prepared by dissolving 2.5% by weight of phenyl bis(2,4,6-trimethylbenzoyl) phosphine oxide (CGI-819 commercially available from Ciba Additives) in PRO-629. This mixture was passed through an alumina basic column in the dark.

A lens forming composition was prepared by mixing 685.3 grams of PRO-629 with 10.48 grams of the 2.5% CGI-819 photoinitiator stock solution, 5.3 grams of NMDEA (N -methyldiethanolamine is commercially available from Aldrich Chemicals), 0.6 grams of Tinuvin 400 ultraviolet/visible light absorber stock solution, 7 grams of the Thermoplast Red stock solution, 58.3 grams of the Thermoplast Blue stock solution, 55.5 of the Oil Soluble Blue II stock solution, 29.2 grams of the Zapon Green 936 stock solution, 68.1 grams of the Zapon Brown 286 stock solution, 38.9 grams of the Zapon

Brown 287 stock solution, and 41.3 grams of the Thermoplast Yellow 104 stock solution. The resulting lens forming composition contained the following components:

Material	% by weight
Bisphenol A bis allyl carbonate	13.35%
Tripropyleneglycol diacrylate	25.13%
Tetraethyleneglycol diacrylate	16.49%
Trimethylolpropane triacrylate	15.71%
Hexanediol dimethacrylate	28.75%
Thermoplast Red	7.0 ppm
Zapon Brown 286	68.1 ppm
Zapon Brown 287	38.9 ppm
Oil Soluble Blue II	55.5 ppm
Thermoplast Blue	58.3 ppm
Zapon Green 936	29.2 ppm
Thermoplast Yellow 104	41.3 ppm
NMDEA	0.53%
CGI-819	262 ppm
Tinuvin 400	30 ppm

An 80mm diameter flattop concave glass mold with a distance radius of curvature of 6.0 diopters was cleaned and coated as described in Example 10.

An 80 mm diameter convex mold with radii of curvature of 6.05 diopters was cleaned and coated in the same fashion except that no pooling of the coating composition occurred in the center of the mold when the composition was dispensed thereto.

The concave and convex molds were then coated with a cured adhesion-promoting coating composition. By providing such a coating, the adhesion between the casting surface of the glass mold and the curing lens forming composition was increased,

thereby reducing the possibility of premature release of the lens from the mold. The coating also provided abrasion resistance, chemical resistance, and improved cosmetics to the finished lens.

The concave and convex molds were then assembled and placed within a lens curing unit as described in Example 10.

An activating light filter was then placed on top of the back mold. The filter was approximately 80 mm in diameter, which is the same as the mold diameter. It had a plano configuration with a thickness of 3.1 mm. This filter transmitted approximately 30% of the incident activating light from the source as measured using the IL1400 radiometer with a XRL-340B detector head. The filter was taken from a group of previously made filters. The fabrication of these filters was discussed in Example 10.

The mold/gasket assembly containing the lens forming composition was then irradiated with six consecutive doses of activating light totaling approximately 1725 mJ/cm^2, as previously measured using the IL-1400 Radiometer equipped with the XLR-340B detector, at the plane of the mold cavity with no filter or any intervening media between the light source and the plane. The mold/gasket assembly was then turned over on the stage so that the front mold was facing upward. The entire assembly was then exposed to six more doses of activating light totaling approximately 1725 mJ/cm^2. The mold/gasket assembly was removed from the curing chamber. The gasket was removed from the molds, and the assembly was placed in a vertical orientation in a rack such that the non-casting faces of both the front and back molds were exposed to ambient room temperature air for a period of approximately ten minutes. At this point, the assembly was returned to the lens curing chamber and was dosed with four exposures totaling 600 mJ/cm^2 directed toward the back mold and four exposures totaling 600 mJ/cm^2 directed toward the front mold.

The lens was removed from the mold assembly and post-cured as described in Experiment 10.

The resulting lens was approximately 74 mm in diameter, had a center thickness of 2.7 mm, and a distance focusing power of +0.06 diopters. The resultant lens was dark green/grayish in color and could be used as a sunglass lens. The optics of the lens were crisp, without aberrations. The lens exhibited visible light transmission of approximately 10%. When scanned with a Hewlett Packard Model UV-Vis spectrophotometer, the lens transmitted virtually no light at wavelengths less than 650 nm.

The sunglass lens of this example was cured using activating light even though the lens forming composition included ultraviolet/visible absorbing fixed pigments. Since such fixed pigments tend to absorb a portion of the activating light strongly, the activating light might not have penetrated to the depths of the lens forming composition. The lens forming composition, however, contained a co-initiator in conjunction with a photoinitiator to help promote the curing of the entire lens forming composition. The present example thus demonstrates that a sunglass lens containing ultraviolet/visible light absorbing fixed pigments may be cured using activating light, which includes ultraviolet/visible light, to initiate polymerization of a lens forming composition that contains a photoinitiator/co-initiator system.

EXAMPLE 13: Altering the Activated color of a Photochromic Lens

According to a preferred embodiment, a polymerizable mixture of PRO-629 (see above for a description of the components of PRO-629), fixed pigments, a photoinitiator/co-initiator, and two photochromic compounds was prepared in a manner similar to that described in Example 12. The resulting lens forming composition includes PRO-629, and the following components:

Material	amount
IRG-184	80 ppm
IRG 819	280 ppm
CN-384	1.0 %
CN-386	1.0 %
Thermoplast Blue	0.67 ppm
Thermoplast Red	0.04 ppm
Reversacol Sea Green	300 ppm
Reversacol Berry Red	600 ppm

After the lens forming composition was prepared, a variety of light effectors were added to the lens forming composition described above. The modified lens forming composition was then placed within a mold cavity, prepared as described in Example 12.

SAMPLE	EFFECTOR	AMOUNT	EFFECTOR UV ABSORBANCE	ACTIVATED COLOR
S9	None	------------	---------	Gray
S10	MEHQ	350 ppm	294-317 nm	Brown
S11	Tinuvin 400	1130 ppm	295-390 nm	Aqua-Green
S12	ITX	500 ppm	280-415 nm	Yellow-Green
S13	IRG-369	300 ppm	290-390 nm	Green

Table 8

Both sides of the mold assembly was irradiated with two doses of actinic light (e.g., light having a wavelength above about 380 nm). The first dose was applied for between 20 to 40 seconds. The final dose was applied for about 5 minutes. The resulting lens was demolded and treated with additional actinic light in a post-cure unit. The formed lens was exposed to sunlight and the activated color of the lens observed. Table 8

summarizes the results when MEHQ, Tinuvin 400, ITX, and IRG-369 are used as light effectors. S9 represents a lens formed without any added light effectors.

The activated color of the formed lens was noted after exposing the formed lens to sunlight. The presence of light effectors can have a significant effect on the color of the lens. It should be noted that this change in color may be obtained without altering the relative ratio of the photochromic compounds (i.e., Berry Red and Sea Green). MEHQ which exhibits absorption in the low ultraviolet light region tends to shift the color of the lens toward red, thus causing the lens to take on a brown color when exposed to sunlight. The absorbers Tinuvin 400, ITX, and IRG-369 all tend to produce lenses having various green shades. Because of the broad photochromic activating light absorbance range of these compounds they may be effecting the photochromic activity of both photochromic compounds.

The above examples represent specific examples of how an activated color of a lens may be altered by the addition of a light effector to a lens forming composition. By running similar studies with other light effectors, the activated color of a lens may be adjusted to a variety of different colors (e.g., red, orange, yellow, green, blue, indigo, or violet) without changing the nature of the photochromic compounds.

FURTHER IMPROVEMENTS

In an embodiment, a lens forming composition may be cured into a variety of different lenses. The lens forming composition includes an aromatic containing polyether polyethylenic functional monomer, a co-initiator composition configured to activate curing of the monomer, and a photoinitiator configured to activate the co-initiator composition in response to being exposed to activating light. The lens forming composition may include other components such as ultraviolet light absorbers and photochromic compounds. Lenses which may be cured using the lens forming

composition include, but are not limited to, spheric single vision, aspheric single vision lenses, flattop bifocal lenses, and asymmetrical progressive lenses.

One lens forming composition, herein referred to as OMB-99, includes a mixture of the following monomers. The OMB-99 mixture is commercially available as "OMB-99 Clear Monomer" from Optical Dynamics Corporation, Louisville Kentucky.

OMB-99

98.25 %	Ethoxylated$_{(4)}$bisphenol A dimethacrylate (CD-540)
0.75 %	Difunctional reactive amine coinitiator (CN-384)
0.75 %	Monofunctional reactive amine coinitiator (CN-386)
0.15 %	Phenyl bis(2,4,6-trimethylbenzoyl) phosphine oxide (Irgacure-819)
0.10 %	2-(2H-Benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol
0.87 ppm	Thermoplast Blue 684
0.05 ppm	Thermoplast Red LB 454

Another lens forming composition, herein referred to as Phases II, includes a mixture of the following monomers. The presence of photochromic compounds allows the Phases II composition to be used to form photochromic lenses.

Phases II

97.09 %	Ethoxylated(4)bisphenol A dimethacrylate (CD-540)
1.4 %	Difunctional reactive amine coinitiator (CN-384)
1.4 %	Monofunctional reactive amine coinitiator (CN-386)
0.09 %	Phenyl bis(2,4,6-trimethylbenzoyl) phosphine oxide (Irgacure-819)
0.9 ppm	Thermoplast Red LB 454
50 ppm	Variacrol Blue D
73.5 ppm	Variacrol Yellow
145 ppm	Berry Red
29 ppm	Palatinate Purple

55.5 ppm	Corn Yellow
62 ppm	Sea Green
85 ppm	Plum Red

The Phases II mixture is commercially available as "PHASES II Monomer" from Optical Dynamics Corporation, Louisville Kentucky.

A lens forming composition which includes an aromatic containing polyether polyethylenic functional monomer, a co-initiator composition and a photoinitiator may be used to form a variety of prescription eyeglass lenses, including eyeglass lenses which have a sphere power ranging from about +4.0 diopter to about –6.0 diopter. The lenses formed from this lens forming composition are substantially free of distortions, cracks, patterns and striations, and that have negligible yellowing, in less than thirty minutes by exposing the lens forming composition to activating light and heat. An advantage of the lens forming composition is that it exhibits increased adhesion to the molds. This may reduce the incidence of premature release of the formed lens from the molds. Additionally, the use of adhesion promoting agents, typically applied to the molds to prevent premature release, may no longer be necessary.

The increased adhesion of the lens forming composition to the molds allows curing of the lens forming composition at higher temperatures. Typically, control of the temperature of the lens forming composition may be necessary to prevent premature release of the lens from the molds. Premature release may occur when the lens forming composition shrinks as it is cured. Shrinkage typically occurs when the lens forming composition is rapidly heated during curing. Lens forming compositions which include an aromatic containing polyether polyethylenic functional monomer, a co-initiator composition and a photoinitiator may reduce the incidence of premature release. The increased adhesion of this lens forming composition may allow higher curing temperatures to be used without increasing the incidence of premature release. It is also

believed that this lens forming composition may exhibit less shrinkage during curing which may further reduce the chance of premature release.

An advantage of curing at higher temperatures is that an eyeglass lens having a high crosslink density may be formed. The crosslink density of an eyeglass lens is typically related to the curing temperature. Curing a lens forming composition at a relatively low temperature leads to a lower crosslink density than the crosslink density of a lens cured at a higher temperature. Lenses which have a higher crosslink density generally absorb tinting dyes substantially evenly without blotching or streaking. Lenses which have a high crosslink density also may exhibit reduced flexibility.

The formation of lenses involves: 1) Preparing the mold assembly; 2) Filling the mold assembly with the lens forming composition; 3) Curing the lens; 4) Post-curing the lens; and 5) Annealing the lens. Optionally, the lens may be coated before use. The formation of lenses may be accomplished using the plastic lens curing apparatus described above.

The preparation of a mold assembly includes selecting the appropriate front and back molds for a desired prescription and lens type, cleaning the molds, and assembling the molds to form the mold assembly. The prescription of the lens determines which front mold, back mold, and gasket are used to prepare the mold assembly. In one embodiment, a chart which includes all of the possible lens prescriptions may be used to allow a user to determine the appropriate molds and gaskets. Such a chart may include thousands of entries, making the determination of the appropriate molds and gaskets somewhat time consuming.

In a preferred embodiment, the controller 50 of the plastic lens curing apparatus 10 (see FIG. 1) will display the appropriate front mold, back mold, and gasket identification markings when a prescription is submitted to the controller. The controller

will prompt the user to enter the 1) the monomer type; 2) the lens type; 3) spherical power; 4) cylindrical power; 5) axis; 6) add power, and 7) the lens location (i.e., right or left lens). Once this information is entered the computer will determine the correct front mold, back mold and gasket to be used. The controller may also allow a user to save and recall prescription data.

FIG. 40 shows an embodiment of a front panel for the controller 50. The controller includes an output device 610 and at least one input device. A variety of input devices may be used. Some input devices include pressure sensitive devices (e.g., buttons), movable data entry devices (e.g., rotatable knobs, a mouse, a trackball, or moving switches), voice data entry devices (e.g., a microphone), light pens, or a computer coupled to the controller. Preferably the input devices include buttons 630, 640, 650 and 660 and a selection knob 620. The display panel preferably displays the controller data requests and responses. The output device may be a cathode ray tube, an LCD panel, or a plasma display screen.

When initially powered, the controller will preferably display a main menu, such as the menu depicted in FIG. 40. If the main menu is not displayed, a user may access the main menu by pressing button 650, which may be labeled Main Menu. In response to activating the Main Menu button 650, the controller will cause the main menu screen to be displayed. As depicted in FIG. 40, a display screen offers a number of initial options on the opening menu. The options may include 1) NEW Rx; 2) EDIT Rx; and 3) VIEW Rx. The main menu may also offer other options which allow the operator to access machine status information and instrument setup menus. The scrolling buttons 630 preferably allow the user to navigate through the options by moving a cursor 612 which appears on the display screen to the appropriate selection. Selection knob 620 is preferably configured to be rotatable to allow selection of options on the display screen. Knob 620 is also configured to allow entry of these items. In one embodiment, selection knob 620 may be depressed to allow data entry. That is, when the appropriate selection is

made, the knob may be pushed down to enter the selected data. In the main menu, when the cursor 612 is moved to the appropriate selection, the selection may be made by depressing the selection knob 620.

Selection of the NEW Rx menu item will cause the display screen to change to a prescription input menu, depicted in FIG. 41. The prescription input menu will preferably allow the user to enter data pertaining to a new lens type. The default starting position will be the lens monomer selection box. Once the area is highlighted, the selection knob 620 is rotated to make a choice among the predetermined selections. When the proper selection is displayed, the selection knob may be pushed down to enter the selection. Entry of the selection may also cause the cursor to move to the next item on the list. Alternatively, a user may select the next item to be entered using the scrolling arrows 630.

Each of the menu items allows entry of a portion of the lens prescription. The lens prescription information includes 1) the monomer type; 2) the lens type; 3) lens location (i.e., left lens or right lens); 4) spherical power; 5) cylindrical power; 6) axis; and 7) add power. The monomer selection may include choices for either clear or photochromic lenses. The lens type item may allow selection between spheric single vision, aspheric single vision lenses, flattop bifocal lenses, and asymmetrical progressive lenses. The sphere item allows the sphere power of the lens to be entered. The cylinder item allows the cylinder power to be entered. The axis item allows the cylinder axis to be entered. The add item allows the add power for multifocal prescriptions to be added. Since the sphere power, cylinder power, cylinder axis, and add power may differ for each eye, and since the molds and gaskets may be specific for the location of the lens (i.e., right lens or left lens), the controller preferably allows separate entries for right and left lenses. If an error is made in any of the entry fields, the scrolling arrows 630 preferably allow the user to move the cursor to the incorrect entry for correction.

After the data relating to the prescription has been added, the controller may prompt the user to enter a job number to save the prescription type. This preferably allows the user to recall a prescription type without having to renter the data. The job number may also be used by the controller to control the curing conditions for the lens. The curing conditions typically vary depending on the type and prescription of the lens. By allowing the controller access to the prescription and type of lens being formed, the controller may automatically set up the curing conditions without further input from the user.

After the job is saved, the display screen will preferably display information which allows the user to select the appropriate front mold, back mold and gasket for preparing the lens, as depicted in FIG. 42. This information is preferably generated by the use of a stored database which correlates the inputted data to the appropriate lenses and gasket. The prescription information is also summarized to allow the user to check that the prescription has been entered correctly. The mold and gasket information may be printed out for the user. A printer may be incorporated into the controller to allow print out of this data. Alternatively, a communication port may be incorporated into the controller to allow the data to be transferred to a printer or personal computer. Each of the molds and gaskets has a predetermined identification marking. Preferably, the identification markings are alphanumeric sequences. The identification markings for the molds and gasket preferably correspond to alphanumeric sequences for a library of mold members. The user, having obtained the mold and gasket identification markings, may then go to the library and select the appropriate molds and gaskets.

The controller is preferably configured to run a computer software program which, upon input of the eyeglass prescription, will supply the identification markings of the appropriate front mold, back mold and gasket. The computer program includes a plurality of instructions configured to allow the controller to collect the prescription information, determine the appropriate front mold, back mold, and gasket required to a

form a lens having the inputted prescription, and display the appropriate identification markings for the front mold, back mold and gasket. In one embodiment, the computer program may include an information database. The information database may include a multidimensional array of records. Each records may include data fields corresponding to identification markings for the front mold, the back mold, and the gasket. When the prescription data is entered, the computer program is configured to look up the record corresponding to the entered prescription. The information from this record may be transmitted to the user, allowing the user to select the appropriate molds and gasket.

In one embodiment the information database may be a three dimensional array of records. An example of a portion of a three dimensional array of records is depicted in Table 9. The three dimensional array includes array variables of sphere, cylinder, and add. A record of the three dimensional array includes a list of identification markings. Preferably this list includes identification markings for a front mold (for either a left or right lens), a back mold and a gasket. When a prescription is entered the program includes instructions which take the cylinder, sphere and add information and look up the record which is associated with that information. The program obtains from the record the desired information and transmits the information to the user. For example, if a prescription for left lens having a sphere power of +1.00, a cylinder power of –0.75 and an add power of 2.75 is entered, the front mold identification marking will be FT-34, the back mold identification marking will be TB-101, and the gasket identification marking will be G25. These values will be transmitted to the user via an output device. The output device may include a display screen or a printer. It should be understood that the examples shown in Table 9 represent a small portion of the entire database. The sphere power may range from +4.00 to -4.00 in 0.25 diopter increments, the cylinder power may range from 0.00 diopters to -2.00 diopters in 0.25 diopter increments, and the add power may range from +1.00 to +3.00 in 0.25 diopter increments.

ARRAY VARIABLES			IDENTIFICATION MARKINGS			
Sphere	Cylinder	Add	**Front (Right)**	**Front (Left)**	**Back**	**Gasket**
+1.00	-0.75	+1.25	FT-21	FT-22	TB-101	G25
+1.00	-0.75	+1.50	FT-23	FT-24	TB-101	G25
+1.00	-0.75	+1.75	FT-25	FT-26	TB-101	G25
+1.00	-0.75	+2.00	FT-27	FT-28	TB-101	G25
+1.00	-0.75	+2.25	FT-29	FT-30	TB-101	G25
+1.00	-0.75	+2.50	FT-31	FT-32	TB-101	G25
+1.00	-0.75	+2.75	FT-33	FT-34	TB-101	G25
+1.00	-0.75	+3.00	FT-35	FT-36	TB-101	G25
+0.75	-0.75	+1.00	FT-19	FT-20	TB-102	G25
+0.75	-0.75	+1.25	FT-21	FT-22	TB-102	G25
+0.75	-0.75	+1.50	FT-23	FT-24	TB-102	G25
+0.75	-0.75	+1.75	FT-25	FT-26	TB-102	G25
+0.75	-0.75	+2.00	FT-27	FT-28	TB-102	G25
+0.75	-0.75	+2.25	FT-29	FT-30	TB-102	G25
+0.75	-0.75	+2.50	FT-31	FT-32	TB-102	G25
+0.75	-0.75	+2.75	FT-33	FT-34	TB-102	G25
+0.75	-0.75	+3.00	FT-35	FT-36	TB-102	G25
+0.50	-0.75	+1.00	FT-19	FT-20	TB-103	G25
+0.50	-0.75	+1.25	FT-21	FT-22	TB-103	G25

Table 9

A second information database may include information related to curing the lens forming composition based on the prescription variables. Each record may include information related to curing clear lenses (i.e., non-photochromic lenses) and photochromic lenses. The curing information may include filter information, initial curing dose information, postcure time and conditions, and anneal time. An example of a portion of this database is depicted in Table 10. Curing conditions typically depend on the sphere power of a lens, the type of lens being formed (photochromic or non-photochromic), and whether the lens will be tinted or not. Curing information includes type of filter being used, initial dose conditions, postcure time, and anneal time. A filter with a 50 mm aperture (denoted as "50 mm") or a clear plate filter (denoted as "clear") may be used. Initial dose is typically in seconds, with the irradiation pattern (e.g., top and bottom, bottom only) being also designated. The postcure time represents the amount of time the mold assembly is treated with activating light and heat in the postcure unit. The anneal time represents the amount of time the demolded lens is treated with heat after the lens is removed from the mold assembly. While this second database is depicted as a separate database, the database may be incorporated into the mold and gasket database by adding the lens curing information to each of the appropriate records.

The controller may also be used to control the operation of the various components of the plastic lens curing apparatus. A series of input devices 640 may allow the operation of the various components of the system. The input devices may be configured to cause the commencement of the lens coating process (640a), the cure process (640b), the postcure process (640c), and the anneal process (640d).

In an embodiment, activating any of the input devices 640 may cause a screen to appear requesting a job number corresponding to the type of lenses being formed. The last job used may appear as a default entry. The user may change the displayed job number by cycling through the saved jobs. When the proper job is displayed the user may enter the job by depressing the selection knob.

LENS INFORMATION			CURING INFORMATION			
Sphere	**Lens Type**	**Tinted**	**Filter**	**Initial Dose**	**Postcure Time**	**Anneal Time**
+2.25	Clear	No	50 mm	90 Sec. Top and Bottom	13 Min.	7 Min.
+2.25	Clear	Yes	50 mm	90 Sec. Top and Bottom	15 Min.	7 Min.
+2.25	Photochromic	No	50 mm	90 Sec. Top and Bottom	13 Min.	7 Min.
+2.00	Clear	No	Clear	7 Sec. Bottom	13 Min.	7 Min.
+2.00	Clear	Yes	Clear	7 Sec. Bottom	15 Min.	7 Min.
+2.00	Photochromic	No	Clear	15 Sec. Bottom	13 Min.	7 Min.

Table 10

After the job has been entered, the system will be ready to commence the selected function. Activating the same input device again (e.g., depressing the button) will cause the system to commence the selected function. For example, pressing the cure button a second time may cause a preprogrammed cure cycle to begin. After the selected function is complete the display screen may display a prompt informing the user that the action is finished.

The main menu may also include selections allowing a saved job to be edited. Returning to the main menu screen, depicted in FIG. 40, selecting the edit menu item will cause an interactive screen to be displayed similar to the input screen. This will allow a user to change the prescription of a preexisting job. The view menu item will allow a user to view the prescription information and mold/gasket selection information from an existing job.

Once the desired mold and gasket information has been obtained, the proper molds and gasket are selected from a collection of molds and gaskets. The molds may be placed into the gasket to create a mold assembly. Prior to placing the molds in the gasket, the molds are preferably cleaned. In one embodiment, the molds may be sprayed with a mixture of isopropyl alcohol and water and wiped dry. Alternatively, they may be spin-cleaned by mounting them on the spin coating unit (e.g., the spin coating units depicted in FIG. 2). The mold may be spun while directing streams of solvents such as isopropyl alcohol, acetone, water, or mixtures thereof onto the mold. After application of the cleaning solvent the molds may be dried by continued spinning in the absence of a cleaning solvent. The molds may also be dried with a lint free cleaning cloth.

The clean molds are placed on the gasket to form a mold assembly. The front mold is preferably placed on the gasket first. For single vision prescriptions, the front mold does not have to be placed in any particular alignment. For flat-top bifocal or progressive front molds, the molds are preferably aligned with alignment marks positioned on the gasket. Once the front mold has been placed into the gasket, the back mold is placed onto the gasket. If the prescription calls for cylinder power, the back mold must be aligned with respect to the front mold. If the prescription is spherical (e.g., the lens has no cylinder power), the back mold may be placed into the gasket without any special alignment. Once assembled the mold assembly will be ready for filling.

The lens forming composition is typically stored at temperatures below about 100 °F. At these temperatures, however, the lens forming composition may be relatively viscous. The viscosity of the solution may make it difficult to fill a mold cavity without creating bubbles within the lens forming composition. The presence of bubbles in the lens forming composition may cause defects in the cured eyeglass lens. To reduce the viscosity of the solution, and therefore reduce the incidence of air bubbles during filling of the mold cavity, the lens forming composition may be heated prior to filling the mold

cavity. In an embodiment, the lens forming composition may be heated to a temperature of about 70 °F to about 220 °F, preferably from about 130 °F to about 170 °F prior to filing the mold cavity.. Preferably, the lens forming composition is heated to a temperature of about 150 °F prior to filling the mold cavity.

The lens forming composition may be heated by using an electric heater, an infrared heating system, a hot air system, a hot water system, or a microwave heating system. Preferably, the lens forming composition is heated in a fill system, such as depicted in FIG. 43. The fill system includes a body 1500 configured to hold the lens forming composition, a heating system 1510 coupled to the body, and a conduit 1520 for transferring the heated lens forming composition from the body to a mold assembly.

The body 1500 is preferably formed from stainless steel. The body preferably includes a bottom 1502 and sidewalls 1504 extending upward from the bottom. The top of the body 1500 is preferably open to allow the lens forming composition to be introduced into the body. The body may include a lid (depicted in FIG. 50) to cover the top of the body after the lens forming composition has been added.

A heating system 1510 is preferably coupled to the body. The heating system 1510 is preferably configured to heat the lens forming composition to a temperature of between about 80 °F to about 220 °F. Preferably a resistive heater is used to heat the lens forming composition. Other heating systems such as hot air system, hot water systems, and infrared heating systems may also be used.

The heating system is preferably disposed within the body, as depicted in FIG. 43. In an embodiment, the body may be divided into a main chamber 1506 and a heating system chamber 1508. The lens forming composition is preferably disposed within the main chamber 1506, while the heating system 1510 is preferably disposed within the heating system chamber 1508. The heating system chamber 1508 preferably isolates the

heating system 1510 from the main chamber 1506 such that the lens forming composition is inhibited from contacting the heating system. Typically, the heating system 1510 may attain temperatures significantly higher than desired. If the heating system 1510 were to come into contact with the lens forming composition, the higher temperature of the heating system may cause the contacted lens forming composition to become partially polymerized. By isolating the heating system 1510 from the lens forming composition such partial polymerization may be avoided. To further prevent partial polymerization, the heating system is preferably insulated from the bottom surface of the main chamber. An insulating material may be placed between the heating system and the bottom of the main chamber. Alternatively, an air gap may be formed between the heating system and the bottom of the main chamber to prevent overheating of the bottom of the main chamber.

A thermostat 1530 may be placed within the chamber, preferably in contact with the lens forming composition. The thermostat 1530 preferably monitors the temperature of the lens forming composition. A controller 1540 may be coupled to the thermostat 1530 and the heating system 1510. The controller 1540 preferably monitors the temperature of the lens forming composition and controls the heating system 1510 to keep the lens forming composition at a predetermined temperature. For example, as the lens forming composition becomes cooler the controller may activate the heating system 1510 to heat the lens forming composition back to the desired temperature. The controller 1540 may be a computer, programmable logic controller, or any of other known controller systems known in the art. These systems may include a proportional-integral ("PI") controller or a proportional-integral-derivative ("PID") controller.

A conduit 1520 is preferably coupled to the body 1500 for transferring the lens forming composition out of the body. The conduit 1520 preferably includes an inlet 1522 and an outlet 1524. The lens forming composition preferably enters the conduit 1520 from the body via the inlet 1522, passes through the conduit, and exits the conduit via the

outlet 1524. The conduit 1520 may be substantially flexible. A flexible conduit may allow the outlet of the conduit to be aligned with a fill port of a mold assembly.

The inner width 1526 of the conduit is herein defined as the width of the internal space defined by the conduit sidewalls. In an embodiment, the inner width 1526 is variable over the length of the conduit. Preferably, the inner width 1526 is substantially wider near the body 1510 and narrows near the outlet 1524. The narrowing of the inner width 1526 allows the lens forming solution disposed within the conduit 1520 to remain warm before dispensing. The portion of the conduit proximate the body 1510 is preferably wider than the portion of the conduit proximate the outlet 1524. This wider portion of the conduit allows better heat exchange with the lens forming composition in the body. The narrower portion of the conduit allows better control of the flow rate of the lens forming composition as it passes through the conduit.

An elongated member 1550 is preferably positioned near the outlet of the conduit. The elongated member 1550 is preferably movable within the conduit. The elongated member 1550 preferably inhibits the flow of lens forming composition through the conduit when the elongated member is in a closed position. The elongated member may be moved into an open position such that the lens forming composition may flow through the conduit. The elongated member 1550 is preferably composed of stainless steel covered with a chemically inert plastic (e.g., a polyacetal plastic such as DELRIN). The use of a plastic coating allows a more leak resistant fit between the elongated member and the conduit.

As depicted in FIG. 44, the elongated member 1550 is in a closed position. The elongated member 1550 is preferably oriented perpendicular to the longitudinal axis of the conduit, as depicted in FIG. 44. The elongated member 1550 preferably resides in a channel 1552 extending through the conduit. In a closed position, the elongated member 1550 may extend to the outer surface of the conduit near the outlet 1524. Preferably, the

elongated member 1550 extends past the outer surface of the conduit 1520 proximate the outlet 1524, when in the closed position. Configuring the elongated member 1550 such that it extends past the outer surface of the conduit may inhibit any residual lens forming composition from building up near the outlet. As the elongated member 1550 is extended toward the outlet any lens forming composition present in the channel 1552 is preferably forced out, leaving the channel substantially clear of lens forming composition. The outlet may be subsequently cleaned by removing the excess lens forming composition from the outer surface of the conduit and the elongated member.

When in the open position, as depicted in FIG. 45 and FIG. 46, the elongated member 1550 is positioned away from the outlet. The end of the elongated member has been moved past a portion of the inner surface 1554 of the conduit such that the lens forming solution may flow through the conduit into the channel 1552. The elongated member may be positioned to control the flow of the lens forming composition through the conduit. For example, as depicted in FIG. 45, the elongated member, although in an open position, still partially blocks the conduit, thus partially inhibiting flow of the lens forming composition through the conduit. As the elongated member is moved further away from the outlet, the flow may of the lens forming composition may increase. The flow rate of the lens forming composition may reach a maximum when the elongated member no longer blocks the conduit, as depicted in FIG. 46.

The interaction of the elongated member 1550 with the movable member 1560 allows the elongated member to be positioned in either a closed or open position. The movable member 1560 preferably includes a groove 1562 formed within the movable member. The groove 1562 preferably extends from a bottom surface of the movable member 1560 toward an upper surface of the movable member. The groove 1562 preferable partially extends through the movable member 1560, stopping before the upper surface of the movable member is reached. The distance from the bottom surface of the movable member 1560 to the top of the groove is herein referred to as the height of the

groove. The height of the groove 1562 is preferably varied along the length of the groove. Preferably the height of the groove has a minimum value and a maximum value. The inner surface of the groove is preferably tapered such that the height of the groove gradually increases from a minimum value to a maximum value. The tapered inner surface may be a linear taper or non-linear taper (i.e., curved).

A movable member 1560 is preferably coupled to the elongated member 1550 to control the positioning of the elongated member within the conduit. The elongated member 1550 preferably extends into the groove 1562 of the movable member 1560, as depicted in FIGS. 44-46. An elastic member 1564 may be coupled to the elongated member 1550 to exert a force against the elongated member. The force from the elastic member 1564 preferably forces the elongated member 1550 into the groove 1562. The elastic member 1564 is preferable positioned within the channel 1552 formed in the conduit. The elastic member is preferably a spring. The elongated member 1550 preferably includes an annular member 1554 positioned proximate a first end of the elongated member, the first end of the elongated member being positioned distal to the outlet 1524. The annular member 1554 is preferably coupled to the elastic member 1564. The elastic member 1564 preferably exerts a force against the annular member 1554. The force against the annular member 1554 preferably causes the annular member, and thus the elongated member 1550, to move out of the channel 1552 away from the conduit outlet 1524 and into the groove 1562 of the movable member. The movable member 1560 prevents the elongated member 1550 from being forced from the conduit.

In one embodiment, the movable member 1560 is a substantially circular knob, as depicted in FIGS. 47 and 48. FIG. 47 represents a cut-away perspective view of the knob 1560. The knob 1560 is configured to rotate such that rotation of the knob causes the elongated member 1550 to move from a closed position to an open position, or from an open position to a closed position. The knob 1560 includes a circular groove 1562 formed within the knob. The groove 1562 is preferably tapered such that the height of

the groove varies along the groove. The groove 1562 may only extend through a portion of the knob 1560. For example, the groove 1562 may be a semi-circular groove, ending at the midpoint of the movable member 1560. The ends of the groove 1562 may be used to prevent overturning of the knob.

The center of the knob 1560 may include an indentation 1568 configured to hold a mounting pin which couples the knob to the conduit. Referring back to FIG. 44, the movable member is preferably coupled to the conduit via a pin 1570. The pin includes a lower portion 1572 and an upper portion 1554. The lower portion 1552 may be threaded to couple the pin to the conduit. The upper portion 1554 is substantially non-threaded. The upper section 1554 preferably serves as a center point around which the knob 1560 is rotatable. In one embodiment, the pin 1554 may be a spring washer. A spring washer allows the knob to be easily rotated, while supplying a small amount of tension to the knob.

Referring back to FIGS. 44 -46, the movement of the elongated member 1550 from a closed position to an open position is sequentially depicted. FIG. 44 depicts the system in a closed position. The elongated member 1550 is positioned such that it entirely blocks the conduit. To move the elongated member 1550 to an open position, the knob 1560 may be turned. The elongated member 1550, will preferably stay within the groove 1562 as the knob is turned. As the height of the groove 1562 increases the elongated member 1550 will move further away from the outlet 1524. The elastic member 1564 will continue to force the elongated member 1550 against the groove 1562 as the knob 1560 is turned. When the elongated member 1550 reaches an intermediate position, as depicted in FIG. 45, the lens forming composition begins to flow through the conduit 1520 and out of the outlet 1524. If the knob 1560 is turned further, the elongated member 1550 will move further away from the outlet 1524. As depicted in FIG. 46, the elongated member 1550 may be moved completely out of the flow path for the lens forming composition.

In order to achieve proper control of the flow rate throughout the outlet, the height of the groove may be varied. As depicted in FIG. 49, the groove may be tapered at more than one angle. FIG. 49 depicts a straightened out cross sectional view of a groove. It should be understood that while depicted in a linear manner, the groove is actually semi-circular in shape. At a first position 1580 the elongated member 1550 is forced into a closed position since the height of the groove is at a minimum. Turning the knob will bring the knob to an intermediate position 1584. At this intermediate position 1584, the lens forming composition may begin to flow through the conduit. Further turning of the knob will bring the knob to a second position 1588 in which the elongated member is in a fully open position.

The groove may be divided into two portions. The first portion extends from the first position 1580 to the intermediate position 1584. The second portion extends from the intermediate position 1584 to the second position 1588. It is preferred that the first portion of the groove have a substantially greater slope than the second portion of the groove. The steeply tapered first portion allows the elongated member to be rapidly moved to an open position. After the intermediate position 1584 has been reached, the groove is tapered to a lesser extent. Thus, the position of the elongated member within he conduit may be finely adjusted to achieve the desired flow rate.

The body of the fill system may be incorporated onto a platform 1590. The platform may include a holder 1592 for the mold assembly, as depicted in FIG. 50. The body 1510 of the fill system may be positioned on the platform 1590. A vertical support 1594 may also be attached to the platform. The body of the fill system may be removable from the platform to allow filling and cleaning of the body. The platform 1590 may also include a lid 1596 for covering the top of the body. A mold assembly 1592 holder is preferably formed on the platform. The mold assembly holder 1592 is configured to hold the mold assembly at a preferred location with respect to the conduit. The mold assembly

holder may secure the mold assembly during filling. In one embodiment, the platform may be configured to be mounted on a table or work bench. Preferably the platform is configured to fit on a portion of a plastic lens curing apparatus (e.g., the apparatus of FIG. 1). Preferably, the fill system is mounted onto a portion of the post cure unit 50 of the plastic lens curing apparatus 10.

To fill the mold assembly, the mold assembly is placed on the mold assembly holders and secured in place. The monomer solution is preferably introduced into the body of the fill station and heated to a temperature of about 150 °F. It is preferred that the monomer solution is stored in the reservoir for a period of time that will allow air bubbles formed during the filling of the body to dissipate. Typically, the monomer is allowed to settle for about 1 hour to about 16 hours before use.

The mold assembly holder may include a clamping system to secure the mold assembly. After the mold assembly is in place, the conduit of the mold fill station is aligned with a fill port of the mold assembly. The lens forming composition is now flowed through the conduit and into the mold assembly. The movable member 1560, may be adjusted to control the flow rate of the monomer.

After the mold assembly is filled, any monomer which may have spilled on the surface of the molds is removed using a lint free wipe. Excess monomer that may be around the edge of the filling port may be removed by using a micro vacuum unit. The mold assembly may be inspected to insure that the mold cavity is filled with monomer. The mold assembly is also inspected to insure that no air bubbles are present in the mold cavity. Any air bubbles in the mold cavity may be removed by rotating the mold assembly such that the air bubbles rise to the top of the assembly.

After the mold assembly has been filled with the monomer and inspected, the mold assembly is transferred to a lens curing unit. A lens curing unit such as lens curing

unit 30 (see FIG. 1) described above may be used. The curing conditions for the lens forming composition may depend on the type of lens being formed and the type of lens forming composition being used. The use of a lens forming composition which includes an aromatic containing polyether polyethylenic functional monomer, a co-initiator composition and a photoinitiator (e.g., the OMB-99 and Phases II compositions) may allow a variety of lenses to be formed using similar lens curing conditions. Table 11 summarizes the lens curing conditions required to cure most types of lenses.

In one embodiment, the curing of the lens forming composition may be accomplished by a procedure involving the application of heat and activating light to the lens forming composition. Initially, activating light is directed toward at least one of the mold members. The activating light is directed for a sufficient time to initiate curing of the lens forming composition. Preferably, the activating light is directed toward at least one of the mold members for a time of less than about 2 minutes. In some embodiments, the activating light is directed toward at least one of the mold members for a time of less than about 25 seconds. In other embodiments, the activating light is directed toward at least one of the mold members for a time of less than about 10 seconds. The activating light is preferably stopped before the lens forming composition is completely cured.

After the curing is initiated, the mold assembly may be transferred to a post cure unit. In the post cure unit the mold assembly is preferably treated with additional activating light and heat to further cure the lens forming composition. The activating light may be applied from the top, bottom, or from both the top and bottom of the curing chamber during the post cure process. The lens forming composition may exhibit a yellow color after the curing is initiated. It is believed that the yellow color is produced by the photoinitiator. As the lens forming composition cures, the yellow color may gradually disappear as the photoinitiator is used up. Preferably, the mold assembly is treated in the post cure unit for a time sufficient to substantially remove the yellow color from the formed eyeglass lens. The mold assembly may be treated in the post cure unit

for a time of up to about 15 minutes, preferably for a time of between about 10 minutes to 15 minutes. After the lens is treated in the post cure unit, the formed eyeglass lens may be demolded and placed back into the post cure unit.

LENS INFORMATION			CURING INFORMATION			
Sphere	**Lens Type**	**Tinted**	**Filter**	**Initial Dose**	**Postcure Time**	**Anneal Time**
+4.00 to +2.25	Clear	No	50 mm	90 Sec. Back and Front	13 Min.	7 Min.
+4.00 to +2.25	Clear	Yes	50 mm	90 Sec. Back and Front	15 Min.	7 Min.
+4.00 to +2.25	Photo		50 mm	90 Sec. Back and Front	13 Min.	7 Min.
+2.00 to -4.00	Clear	No	Clear Plate	7 Sec. Front	13 Min.	7 Min.
+2.00 to -4.00	Clear	Yes	Clear Plate	7 Sec. Front	15 Min.	7 Min.
+2.00 to plano	Photo		Clear Plate	15 Sec. Front	13 Min.	7 Min.
-0.25 to -4.00	Photo		Clear Plate	20 Sec. Back, w/ 7 Sec. Front starting @ 13 Sec. elapsed time.	13 Min.	7 Min.

Table 11

In some instances, it may be desirable to subject the lens to an anneal process. When a lens, cured by the activating light, is removed from a mold assembly, the lens may be under a stressed condition. It is believed that the power of the lens can be more rapidly brought to a final resting power by subjecting the lens to an anneal treatment to relieve the internal stresses developed during the cure. Prior to annealing, the lens may have a power that differs from the desired final resting power. The anneal treatment is believed to reduce stress in the lens, thus altering the power of the lens to the desired final resting power. Preferably, the anneal treatment involves heating the lens at a temperature

between about 200 °F to 225 °F for a period of up to about 10 minutes. The heating may be performed in the presence or absence of activating light.

The use of a lens forming composition which includes an aromatic containing polyether polyethylenic functional monomer, a co-initiator composition and a photoinitiator (e.g., the OMB-99 and Phases II compositions) allows much simpler curing conditions than other lens forming compositions. While pulsed activated light curing sequences may be used to cure the lenses, continuous activating light sequences may also be used, as described in Table 11. The use of continuous activating light sequences allows the lens curing equipment to be simplified. For example, if continuous activating light is used, rather than pulsed light, equipment for generating light pulses is no longer required. Thus, the cost of the lens curing apparatus may be reduced. Also the use of such a lens forming composition allows more general curing processes to be used. As shown in Table 11, seven different processes may be used to cure a wide variety of lenses. This greatly simplifies the programming and operation of the lens curing unit.

Furthermore, the use a lens forming composition which includes an aromatic containing polyether polyethylenic functional monomer, a co-initiator composition and a photoinitiator (e.g., the OMB-99 and Phases II compositions) may alleviate the need for cooling of the lens forming composition during curing. This may further simplify the procedure since cooling fans, or other cooling systems, may no longer be required. Thus, the lens curing apparatus may be further simplified by removing the mold apparatus cooling systems.

Table 11 shows the preferable curing conditions for a variety of lenses. The sphere column refers to the sphere power of the lens. The monomer type is either clear (i.e., non-photochromic) or photochromic. Note that the lens type (e.g., spheric single vision, aspheric single vision lens, flat-top bifocal lens or progressive multifocal lens)

does not significantly alter the lens curing conditions. Tinted refers to whether the formed eyeglass lens will be soaked in a dye bath or not.

Based on the prescription information the lens curing conditions may be determined. There are four curing variables to be set. The type of light filter refers to the filter placed between the lamps and the mold assembly in the curing unit and the post cure unit. The initial does refers to the time that activating light is applied to the lens forming composition in the curing unit. The irradiation pattern (e.g., irradiation of the front mold only, the back mold only, or both molds) is also dependent on the lens being formed. After the initial dose is applied the mold assembly is transferred to the post cure unit where it is treated with activating light and heat. The chart lists the preferred time spent in the post cure chamber. After treatment in the post cure chamber the formed eyeglass lens is removed from the mold assembly. The lens may undergo an annealing process, for the time listed, in which the lens is heated either in the presence or absence of activating light. It should be noted that all of the lens curing processes recited are preferably performed without any cooling of the mold apparatus.

To further illustrate this procedure, the method will be described in detail for the production of a clear, non-tinted lens having sphere power of +3.00. A mold assembly is filled with a non-photochromic monomer solution (e.g., the OMB-99 composition). The mold assembly is placed in a lens curing unit to apply the initial dose to the lens forming composition. The curing of the lens forming composition is preferably controlled by controller 50. As shown in FIG. 40, the controller 50 includes a number of input devices which allow an operator to initiate use of the various components of the plastic lens curing apparatus 10. In an embodiment, buttons 640 may be used to control operation of the coating process (640a), the curing process (640b), the postcure process (640c), and the anneal process (640d). After the mold assembly is placed in the lens curing unit, the curing process button 640b may be pressed to set the curing conditions. In one embodiment, an operator has preloaded the prescription information and saved the

information as described above. Pressing the cure button may cause the controller to prompt the user to enter a reference code corresponding to the saved prescription information. The controller is preferably configured to analyze the prescription information and set up the appropriate initial dose conditions.

After determining the appropriate lens forming conditions, the controller may inform the user of the type of filters to be used. The controller may pause to allow the proper filters to be installed within the lens curing unit. Typically, two types of filters may be used for the initial cure process. The filters are preferably configured to distribute the light so that the activating light which is imparted to the lens molds is properly distributed with respect to the prescription of the lens. A clear plate filter refers to a plate that is substantially transparent to activating light. The clear plate may be composed of polycarbonate or glass. A 50 mm filter refers to filter which includes a 50 mm aperture positioned in a central portion of the filter. The 50 mm aperture is preferably aligned with the mold assembly when the filter is placed in the curing unit. Preferably, two filters are used, the first being placed between the top lamps and the mold assembly, the second being placed between the bottom lamps and the mold assembly.

After the filters have been placed, the user may indicate to the controller that the filters are in place. Alternatively, the controller may include a sensor disposed within the lens curing unit which informs the controller when a filter is placed within the curing unit. After the filters are placed in the curing unit, the controller may prompt the user to ensure that the mold assembly is in the curing unit prior to commencing the curing process. When the filters and mold are in place, the initial dose may be started by the controller. For a clear, non-tinted lens having sphere power of +3.00 the initial dose will be 90 seconds of activating light applied to both the front and back molds. A 50 mm filter is preferably positioned between the top and bottom lamps.

After the initial cure process is completed, the mold assembly is transferred to the post cure unit. The completion of the initial cure process may cause the controller to alert the operator that the process is completed. An alarm may go off to indicate that the process is completed. To initiate the post cure process, the post cure button 640c may be pressed. Pressing the post cure button may cause the controller to prompt the user to enter a reference code corresponding to the saved prescription information. The controller is preferably configured to analyze the prescription information and set up the appropriate post cure conditions. For a clear, non-tinted lens having sphere power of +3.00 the post cure conditions will include directing activating light toward the mold assembly in a heated post cure unit for 13 minutes. The post cure unit is preferably heated to a temperature of about 200 °F to about 225 °F during the post cure process.

After the post cure process is completed, the mold assembly is disassembled and the formed lens is removed from the mold members. The completion of the post cure process may cause the controller to alert the operator that the process is completed. An alarm may go off to indicate that the process is completed. After the molds are removed from the post cure unit, the gasket is removed and the molds placed in a demolding solution. A demolding solution is commercially available as "Q-Soak Solution" commercially available from Optical Dynamics Corporation. The demolding solution causes the lens to separate from the molds. The demolding solution also aids in the subsequent cleaning of the molds. After the lens has been demolded, the lens is preferably cleaned of dust particles using a solution of isopropyl alcohol and water.

In some instances it is desirable that the formed lens undergoes an anneal process. To initiate the anneal process the anneal button 640d may be pressed. Pressing the anneal button will set the conditions for the anneal process. For a clear, non-tinted lens having sphere power of +3.00 the anneal conditions will include heating the lens in the post cure unit, in the absence of activating light, for about 7 minutes. The post cure unit

is preferably heated to a temperature of about 200 °F to about 225 °F during the anneal process.

In one embodiment, the drawer of the post cure unit includes a front row of mold assembly holders and a back row of lens holders. For the post cure process, the mold assemblies are preferably placed in the front row. The front row is preferably oriented under the post cure lamps when the post cure drawer is closed. For the anneal process the lenses are preferably placed in the back row of the post-cure drawer. The back row may be misaligned with the lamps such that little or no activating light reaches the back row.

After the anneal process, the lens may be coated in the coating unit with a scratch resistant hard coat. The lens may also be tinted by placing in a tinting bath. It is believed that tinting of the lens is influenced by the crosslink density of the lens. Typically, a lens having a relatively high crosslink density exhibits more homogenous absorption of the dye. Problems such as blotching and streaking of the dye are typically minimized by highly crosslinked lenses. The crosslink density of a lens is typically controlled by the temperature of curing of the lens. A lens which is cured at relatively high temperatures typically exhibits a crosslink density that is substantially greater than a low temperature cured lens. The curing time may also influence the hardness of a lens. Treating a lens for a long period of time in a post cure unit will typically produce a lens having a greater crosslink density than lenses treated for a shorter amount of time. Thus, to produce lenses which will be subsequently treated in a tinting bath, the lens forming composition is treated with heat and activating light in the post cure unit for a longer period of time than for the production of non-tinted lenses. As shown in table 11, non-tinted clear lenses are treated in the postcure unit for about 13 minutes. For clear lenses which will be subsequently tinted, the post cure time is extended to about 15 minutes, to produce a lens having a relatively high crosslink density.

The formation of flat-top bifocal lenses may also be accomplished using the above described procedure. One problem typical of curing flat-top bifocal eyeglass lenses with activating light is premature release. Flat-top bifocals include a far vision correction zone and a near vision correction region. The far vision correction zone is the portion of the lens which allows the user to see far away objects more clearly. The near vision correction zone is the region that allows the user to see nearby objects clearer. The near vision correction zone is characterized by a semicircular protrusion which extends out from the outer surface of an eyeglass lens. As seen in FIG. 53, the portion of the mold cavity which defines the near vision correction zone 1610 is substantially thicker than the portion of the mold cavity defining the far vision correction zone 1620. Directing activating light toward the mold members causes the polymerization of the lens forming composition to occur. It is believed that the polymerization of the lens forming composition begins at the casting face of the irradiated mold and progresses through the mold cavity toward the opposite mold. For example, irradiation of the front mold 1630 causes the polymerization to begin at the casting surface of the front mold 1632 and progress toward the back mold 1640. As the polymerization reaction progresses, the lens forming composition is transformed from a liquid state to a gel state. Thus, shortly after the front mold 1632 is irradiated with activating light, the portion of the lens forming composition proximate the casting face of the front mold member 1632 will become gelled while the portion of the lens forming composition proximate the back mold member 1640 will remain substantially liquid. If the polymerization is initiated from the back mold 1640, the lens forming composition throughout the far vision correction zone 1620 may become substantially gelled prior to gelation of the lens forming composition in the near vision correction zone proximate the casting surface of the front mold member 1610 (herein referred to as the "front portion of the near vision correction zone"). It is believed that when the gelation of the lens forming composition in the front portion of the near vision correction zone 1610 occurs after the far vision correction zone 1620 has substantially gelled, the resulting strain may cause premature release of the lens.

To reduce the incidence of premature release in flat-top bifocal lenses, it is preferred that polymerization of the lens forming composition in the front portion of the near vision correction zone 1610 is initiated before the portion of the lens forming composition in the far vision correction zone proximate the back mold member 1640 is substantially gelled. Preferably, this may be achieved by irradiating the front mold 1630 with activating light prior to irradiating the back mold 1640 with activating light. This causes the polymerization reaction to begin proximate the front mold 1630 and progress toward the back mold 1640. It is believed that irradiation in this manner causes the lens forming composition in the front portion of the near vision correction zone 1610 to become gelled before the lens forming composition proximate the back mold 1640 becomes gelled. After the polymerization is initiated, activating light may be directed at either mold or both molds to complete the polymerization of the lens forming composition. The subsequent post cure and anneal steps for the production of flat-top bifocal lenses are substantially the same as described above.

Alternatively, the incidence of premature release may also be reduced if the front portion of the near vision correction zone 1610 is gelled before gelation of the lens forming composition extends from the back mold member 1640 to the front mold member 1630. In this embodiment, the polymerization of the lens forming composition may be initiated by irradiation of the back mold 1640. This will cause the gelation to begin proximate the back mold 1640 and progress toward the front mold 1630. To reduce the incidence of premature release, the front mold 1630 is irradiated with activating light before the gelation of the lens forming composition in the far vision correction zone 1620 reaches the front mold. After the polymerization is initiated in the front portion of the near vision correction zone 1610, activating light may be directed at either mold or both molds to complete the polymerization of the lens forming composition. The subsequent post cure and anneal steps for the production of flat-top bifocal lenses are substantially the same as described above.

In another embodiment, a single curing unit may be used to perform the initial curing process, the post cure process, and the anneal process. A lens curing unit is depicted in FIG. 51 and FIG. 52. The curing unit 1230 may include an upper light source 1214, a lens drawer assembly 1216, and a lower light source 1218. Lens drawer assembly 1216 preferably includes a mold assembly holder 1220 (see FIG. 52), more preferably at least two mold assembly holders 1220. Each of the mold assembly holders 1220 is preferably configured to hold a pair of mold members that together with a gasket form a mold assembly. Preferably, the lens drawer assembly may also include a lens holder 1221 (see FIG. 52), more preferably at least two lens holders 1221. The lens holders 1221 are preferably configured to hold a formed eyeglass lens. The lens drawer assembly 1216 is preferably slidingly mounted on a guide 1217. During use, mold assemblies and/or lenses may be placed in the mold assembly holders 1220 or lens holders 1221, respectively, while the lens drawer assembly is in the open position (i.e., when the door extends from the front of the lens curing unit). After the holders have been loaded, the door may be slid into a closed position, with the mold assemblies directly under the upper light source 1214 and above the lower light source 1218. The lens holders and lenses disposed upon the lens holders may not be oriented directly under the upper and lower light sources. As depicted in FIG. 52, the light sources 1214 and 1218 preferably extend across a front portion of the curing unit, while no lamps are placed in the rear portion of the curing unit. When the lens drawer assembly is slid back into the curing unit, the mold assembly holders 1220 are oriented under the lamps, while the lens holders 1221 are oriented in the back portion where no lamps are present. By orienting the holders in this manner curing process which involve light and heat (e.g., post cure processes) and annealing processes, which may involve either application of heat and light or the application of heat only, may be performed in the same unit.

The light sources 1214 and 1218, preferably generate activating light. Light sources 1214 and 1218 may be supported by and electrically connected to suitable fixtures 1242. Lamps 1214 may generate either ultraviolet light, actinic light, visible

light, and/or infrared light. The choice of lamps is preferably based on the monomers and photoinitiator system used in the lens forming composition. In one embodiment, the activating light may be generated from a fluorescent lamp. The fluorescent lamp preferably has a strong emission spectra in the 380 to 490 nm region. A fluorescent lamp emitting activating light with the described wavelengths is commercially available from Philips as model TLD-15W/03. In another embodiment, the lamps may be ultraviolet lights.

In one embodiment, an upper light filter 1254 may be positioned between upper light source 1214 and lens drawer assembly 1216, as depicted in Fig. 51. A lower light filter 1256 may be positioned between lower light source 1218 and lens drawer assembly 1216. Examples of suitable light filters have been previously described. The light filters are used to create a proper distribution of light with regard to the prescription of the eyeglass lens. The light filters may also insulate the lamps from the curing chamber. During post cure and annealing process it is preferred that the chamber is heated to temperatures between about 200 and 225 °F. Such temperatures may have a detrimental effects on the lamps such as shortening the lifetime of the lamps and altering the intensity of the light being produced. The light filters 1254 and 1256, when mounted into the guide 1217, will form an inner chamber which partially insulates the lamps from the heated portion of the chamber. In this manner, the temperatures of the lamps may be maintained within the usual operating temperatures.

Alternatively, a heat barrier 1260 may be disposed within the curing chamber. The heat barrier preferably insulates the lamps from the curing chamber, while allowing the activated light generated by the lamps to pass into the chamber. In one embodiment, the heat barrier may include a borosilicate plate of glass (e.g., PYREX glass) disposed between the light sources and the mold assembly. Preferably, a pair of borosilicate glass plates 1264 and 1262 with an intervening air gap between the plates 1263 serves as the

heat barrier. The use of borosilicate glass allows the activating radiation to pass from the light sources to the lamps without any significant reduction intensity.

Along with the heat barrier 1260 and filter 1254, an opaque plate 1270, may be placed between the light sources and the mold assembly. The opaque plate is substantially opaque toward the activating light. Apertures are preferably disposed in the opaque plate to allow light to pass through the plate onto the mold assemblies.

In order to allow post cure and annealing procedures to be performed, a heating system 1250 is preferably disposed within the curing unit, as depicted in FIG. 52. The heating system 1250 may be a resistive heating system, a hot air system, or an infrared heating system. The heating system 1250 may be oriented along the back side of the curing chamber. The heating system 1250 is preferably disposed at a position between the two filters, such that the heating system is partially insulated from the lamps 1214 and 1218. Preferably, the heating system is configured to heat the curing chamber to a temperature of about 200 °F to about 225 °F.

The incorporation of a heating system into a system which allows irradiation of a mold assembly from both sides will allow many of the above described operations to be performed in a single curing unit. The use of lamps in the front portion of the curing unit, while leaving the back portion of the curing chamber substantially free of lamps, allows both activating light curing steps and annealing steps to performed in the same unit at the same time. Thus the curing conditions described in Table 11 may be performed in a single unit, rather than the two units as described above.

In another embodiment, the method of producing the lenses may be modified such that all of the initial curing process is performed while heat is applied to the lens forming composition. Table 12 shows alternate curing conditions which may be used to cure the lens forming compositions.

LENS INFORMATION			CURING INFORMATION		
Sphere	Lens Type	Tinted	Filter	Curing Conditions	Anneal Time
+4.00 to +2.25	Clear	No	50 mm	90 Seconds Front and Back 13 Minutes Back Temperature 225 °F	7 Min.
+4.00 to +2.25	Clear	Yes	50 mm	90 Seconds Front and Back 15 Minutes Front Temperature 225 °F	7 Min.
+4.00 to +2.25	Photo		50 mm	90 Seconds Front and Back 13 Minutes Front Temperature 225 °F	7 Min.
+2.00 to -4.00	Clear	No	Clear Plate	7 Seconds Front 13 Minutes Back Temperature 225 °F	7 Min.
+2.00 to -4.00	Clear	Yes	Clear Plate	7 Seconds Front 15 Minutes Back Temperature 225 °F	7 Min.
+2.00 to plano	Photo		Clear Plate	15 Seconds Front 13 Minutes Back Temperature 225 °F	7 Min.
-0.25 to -4.00	Photo		Clear Plate	20 Seconds Back w/ 7 Sec. Front starting @ 13 Sec. elapsed time 13 Minutes Back Temperature 225 °F	7 Min.

Table 12

After the mold assembly is filled with the appropriate monomer solution the mold assemblies are placed in the mold assembly holders of the drawer of the curing unit. The drawer is slid back into the curing unit. The curing unit may be preheated to a temperature of about 225 °F prior to placing the mold assemblies in the curing unit. The curing conditions include applying activating light to one or both of the mold members while substantially simultaneously applying heat to the mold assemblies. As shown in

Table 12, the light curing conditions are similar to the previously described conditions. However, the initial dose and the post-cure processes have been combined into a single process. Thus, for the formation of a photochromic lens having a sphere power of +1.50, the mold assemblies are placed in the lens curing unit and irradiated with activating light from the bottom of the unit for about 15 seconds. The curing unit is preferably at a temperature of about 225 °F while the activating light is applied. After 15 seconds, the bottom light is turned off and the mold assemblies are treated with activating light from the top lamps for about 13 minutes. This subsequent treatment with activating light is also performed at a curing chamber temperature of about 225 °F. After the 13 minutes have elapsed, the lights may be turned off, the lens removed from the molds and an anneal process begun.

The anneal process may be performed in the same unit that the cure process is performed. The demolded lens is preferably placed in the lens holders of the curing unit drawer. The curing unit is preferably at a temperature of about 225 °F, when the lens are placed in the curing unit. Preferably, the lens holders are positioned away from the lamps, such that little activating light reaches the lenses when the lamps are on. This allows anneal processed to be performed at the same time that curing processes are performed and within the same curing unit. Lenses that have been formed with a mixture of heating and light typically exhibit crosslink density that are greater than lenses which are cured using combinations of light only curing with light and heat curing.

It should be understood, that the above-described improvements may be used in combination with any of the features of the previously described embodiments.

Further modifications and alternative embodiments of various aspects of the invention will be apparent to those skilled in the art in view of this description. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the invention. It is

to be understood that the forms of the invention shown and described herein are to be taken as the presently preferred embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features of the invention may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description of the invention. Changes may be made in the elements described herein without departing from the spirit and scope of the invention as described in the following claims.